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DEVELOPMENT AND EVALUATION OF A THERMAL PROTECTIVE LIFE PRESERVER FOR COLD WATER IMMERSION

By

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CHAPTER I

INTRODUCTION

In September of 1982, the Federal Aviation Administration (FAA) in Oklahoma City, Oklahoma, requested that the Department of Clothing, Textiles and Merchandising, Oklahoma State University (OSU), design a prototype thermal protective life preserver for passengers in aircraft during over-water flights. Specifications given by the FAA were:

1) The life preserver should provide increased thermal protection in the event of accidental submersion in cold waters

2) The life preserver should provide thirty-five pounds of buoyancy

3) The life preserver should self-right the wearer in five seconds

4) The life preserver should be capable of being donned by an adult in fifteen seconds

5) The life preserver should fit individuals from the 5th percentile of adult females to the 95th percentile of adult males in the United States population

6) The life preserver should meet the airlines' weight and storage specifications

As a safety measure, the FAA requires that all over-

water flights must carry life preservers and other safety flotation devices for civilian passengers and crew. However, no provisions are made to protect immersed victims from cold water. Boutelier (1979) stated that 47 percent of the ocean waters have a temperature of less than 20°C. The ocean waters off the coast of the United States and Canada range from 0°C to 15°C during the winter (Boutelier, 1979). In the United States, 215 airports have large bodies of water near the airport departure and approach areas. The Air Line Pilots Association's committee reports that 78 percent of airliner accidents occur in takeoff, climbing, approach and landing (Brooks, 1985).

The problem of providing thermal protection for individuals accidentally submerged in cold water is acknowledged by military forces, offshore oil industries, and fishing fleets. However, with an increase in oversea air traffic, the FAA is concerned with the safety of civilian passengers who are being exposed to the potential of accidental immersion in cold water. If this type of accident occurs in water below 18°C, special protection is needed if victims are to survive long enough for rescue efforts to be successful (Boutelier, 1979). Currently, the only protection available for civilian passengers is a personal flotation device (PFD) that prevents drowning. Passengers are protected, yet doubt remains as to whether the passengers are sufficiently protected. Three commonly criticized design features of the personal flotation device are: (1) it encompasses only the neck area and no thermal

protection is provided to the rest of the body; (2) the mean donning time for currently used personal flotation devices ranged from 28 to 37.6 seconds (Rasmussen and Steen, 1983); and (3) when inflated, the cells form a "V" which channel the water directly to the face, which increases the possibility of drowning.

If a life preserver provided a measure of thermal protection, the chances of death caused by hypothermia are not only decreased, but the chances of death caused by drowning may also be decreased. For example, Golden (1983, p. 37) reported the problem of drowning in cold water as

> Normally if you keep your back to the wave, the wave goes over the head, but when you stop making that physical effort to keep your back to the waves your legs act as a sea anchor, the top of the body is buoyant, the next wave that comes pushes the top of the body around and you are facing the oncoming wave; you quickly drown in that situation when you lose control of respiration. It depends very much on the frequency of the wave and how much you are able to control your respiration and judge when the next wave is coming. The small scurring wave going across the big wave is difficult to judge. The minute you inhale a bit of water you start a cough reflex and you have lost all control of respiration at that stage and you very quickly drown. It may well be that the fifty percent survival time figure that we have looked at in the graphs is related to that; it is the time when consciousness is impaired to a degree when drowning occurs and that just occurs when you lose about 2 or 3 degrees in body temperature.

Thus, when determining the degree of thermal protection required, the deep body temperature before the time when consciousness is impaired should be considered. According to Beckman, Reeves, and Goldman (1966) conscious muscular activity is lost at 34.4°C.

The following accidents demonstrate the necessity of a thermal protective life preserver (Higgins, Funkhouser, and Saldivar, 1982).

SS Lakonia, December 1963, Ship fire with evacuation:

1) Two hundred passengers and crew, all wearing life preservers, were immersed
2) The rescue operation was effective in approximately three hours
3) All passengers and crew survived
4) The water temperature of 18°C (64°F) was a potential problem (p. 2)

SS Prinsendam, October 1980, Ship fire with evacuation:

1) Five hundred nineteen passengers and crew entered life boats
2) Though less than 100 miles from land, the rescue operation, using ships and helicopters, required 12 hours
3) All passengers and crew survived
4) The water temperature of 14°C (57°F) was a potential problem (p. 2)

Shetland Islands HS-748, July 1981, Unsuccessful aircraft takeoff with water impact 50 meters from land:

1) Most passengers were not able to obtain life preservers from under the seat
2) Airport ground rescue equipment was near the site in two minutes but was not effective
3) Two helicopters were over the site within four minutes but were not effective due to the weather conditions
4) Of the 47 aboard, 17 drowned, ten outside the aircraft
6) The water temperature of 11°C (52°F) was a problem (p. 2)

Washington, D.C., B737, January 1982, Unanticipated aircraft crash into the Potomac River:

1) Of 79 aboard, 73 died of impact injuries, one drowned, and five were rescued

2) A park Police helicopter arrived at the site 21 minutes after impact
3) The one drowning probably did involve the effects of immersion hypothermia. The water temperature of near 0°C (32°F) was a factor (p. 2)

The time it took for an effective rescue operation and the cold water temperatures in the above accidents, indicate a need for a thermal protective life preserver.

Purpose of the Study

The purpose of the study was to develop and evaluate a thermal protective life preserver for cold water immersion.

Objectives

The objectives of this study were to:

1) Develop a prototype thermal protective life preserver that met the FAA specifications.

2) Test and evaluate the thermal response characteristics of human subjects wearing the prototype life preserver and a currently used standard personal flotation device.

3) Estimate a predicted survival time for human subjects wearing the prototype life preserver and a currently used standard personal flotation device.

Hypotheses

The following null hypotheses were tested:

1) There are no significant differences in cooling rate between subjects wearing the prototype life preserver and the standard personal flotation device.

2) There are no significant differences in heart rate between subjects wearing the prototype life preserver and the standard personal flotation device.

Limitations

The following limitations were recognized:

1) The study was limited to male subjects, aged 18 to 35 years.

2) Only one water temperature of 12.8°C (55°F) was used in the study.

3) Only one air temperature of 21.1°C (70°F) was used in the study.

4) The effect on cooling rate below a core temperature of 35°C was not determined.

Definition of Terms

The definitions of the terms used throughout the study are listed as follows:

Cooling Rate: The slope of that portion of the cooling curve that demonstrates an established, fairly uniform rate of decline in rectal temperature.

Accidental Hypothermia: Accidental hypothermia is an unintentional lowering of the central body temperature below 35°C (Boutelier, 1979). Four degrees of hypothermia can be distinguished: slight, when the rectal temperature is between 35 and 34°C; moderate, if it is between 34 and 32°C; serious, if it is between 32 and 25°C; and major if it is below 25°C (Boutelier, 1979).

Donning Time: The time in which an individual is able to put on a life preserver.

Self-right: The ability of the life preserver to put the wearer on his or her back, from a starting face-down position in the water.

CHAPTER II

REVIEW OF LITERATURE

In order to provide protection needed for survival in cold water, literature was reviewed in the following areas: human heat exchange in cold environments, human temperature regulation, physiology of immersion hypothermia, factors that influence cooling rate, and various design concepts best fitted for protection against hypothermia.

Human Heat Exchange in the Cold Environment

The human body exchanges heat with the environment in four different ways: conduction, convection, radiation, and evaporation. During immersion, heat exchange is mainly by conduction and convection; in air, heat exchange occurs in all four ways (Boutelier, 1979).

Conduction

The flow of heat through a medium or between objects in physical contact by the transfer of energy without the physical transfer of material is called thermal conduction (Iampietro and Adams, 1966). Thermal transfer by conduction takes place from within the human body to the skin surface and from the skin to cooler objects with which the body may be in contact. Heat will flow to the cooler sur-

face to reach equilibrium.

Convection

Convection is a means of heat transfer which depends upon the movement of a fluid (air, water) over a surface that is at a different temperature. Heat exchange by convection between the body surface and the surrounding air or water can be reduced by the placement of a material over the body surface that would inhibit fluid movement.

Two types of convection are usually identified. In natural convection, the fluid (air or water) flow is a function of differences in density within the fluid produced by differences in temperature, for example, warm air rising over a warm surface (Iampietro and Adams, 1966). Forced convection, requires external influences to move the fluid, such as swimming, movement of the waves, or wind. In the event of an accidental immersion, forced convection is of greater concern, because of the currents or movement of waves (Boutelier, 1979).

Radiation

Radiation refers to the exchange of electromagnetic energies between facing surfaces that are at different temperatures. The human skin functions as a nearly perfect "black body" emitting and absorbing energy to a high extent (Hardy, 1949). The amount of heat lost by radiation depends not only on the temperature gradient, but also on the

area of skin exposed. Best (1979) reported that in a standing position about 85 percent of the total skin area is exposed for heat radiation.

Clothing modifies radiant heat loss by altering the temperature of the skin surface when the heat exchange is occurring. Boutelier (1979) stated that in the case of accidental immersion, the heat exchange by radiation is negligible when the victim is immersed.

Evaporation

Evaporation refers to the process in which a fluid is converted from a liquid to a gas phase, due to thermal energy (Adams, 1978). At least 20 percent of the total heat loss from man is due to the evaporation of water, approximately two thirds from the skin surface and one third from the respiratory tract (Maclean and Smith, 1977). Evaporative heat loss from the body can be achieved in three ways: insensible perspiration through the skin, insensible water loss from the respiratory tract and regulatory sweating.

Insensible perspiration through the skin occurs by the diffusion of water vapor through the skin. In this manner, the body loses about 900 ml. of water per day. This will result in the loss of 520 kcal of heat per day (Green, 1963). The insensible water loss from the respiratory tract amounts to about 400 ml. of water per day. This will result in the loss of 230 kcal. of heat per day (Green, 1963).

Evaporative cooling is the only mechanism available for the reduction of body temperature in man when the environmental temperature is higher than that of the body. Under severe conditions, the sweat glands are capable of producing 1.5 litres of sweat an hour (Jenson, 1980). This would result in the loss of 870 kcal per hour if it all evaporated.

Human Temperature Regulation

The control of human temperature regulation is effected primarily by the central nervous system (CNS). The CNS integrates the signals coming from the peripheral and central thermal receptors and, if thermal imbalance is detected, the CNS activates the appropriate effector mechanisms in order to alter the temperature.

Three stages are involved: first, structures known as thermoreceptors or thermosensors sense the temperature level of the body. Second, structures known as the thermoregulatory centers integrate the sensed temperatures coming from the thermoreceptors and activate the appropriate effector mechanisms. Third, structures known as effectors, are capable of altering the temperature.

Thermoreceptors

Thermoreceptors are located either in the skin or in the body core, especially in the CNS (Houdas and Ring, 1982). They are termed peripheral thermoreceptors and cen-

tral thermoreceptors respectively.

The peripheral thermoreceptors located within the skin are sensitive to their own temperature. They provide an input for the conscious perception of the ambient temperature and are able to stimulate the thermoregulatory centers to bring about behavioral and/or physiological responses.

The central thermoreceptors are found in various parts of the body. They are most numerous in the CNS, particularly in the anterior hypothalamus. These receptors are stimulated by their own temperature and produce an impulse discharge related to their stimulation (Houdas and Ring, 1982).

Two kinds of thermoreceptors have been distinguished, cold receptors and warm receptors. Cutaneous cold receptors increase their firing rate as the skin is cooled and cutaneous warm receptors increase their firing rate as the skin is warmed. In past research experiments, very small areas have been found that respond only to the sensation of cold and other areas which respond only to the sensation of warmth.

The number of receptors per unit area of skin surface varies with location on the body. The density is generally higher on the face including the ears and tongue. However, regardless of the regional location, the number of cold receptors is 10 to 15 times greater than that of warm receptors. In contrast, the number of warm receptors in the hypothalamus, appears to be fifty times greater than that of the cold receptors (Houdas and Ring, 1982).

Thermoregulatory Centers

The hypothalamus appears to be the major thermoregulatory center (Hensel, 1981) although other parts of the central nervous system, such as the spinal cord and the brain stem also seem to have thermoregulatory responses (Houdas and Ring, 1982). In the hypothalamus, two regions appear to be concerned with heat control. The anterior hypothalamus controls the heat loss by means of skin vasodilation and sweating when the temperature is rising. The posterior hypothalamus is the center for conserving heat and heat production. It controls the heat loss by means of vasoconstriction and heat production by shivering.

The hypothalamus behaves like a thermostat. It compares the temperature at the thermoreceptor sites with a central set-point temperature (approximately 37°C) and then activates the effector mechanisms that will maintain the central body temperature as close as possible to the set-point temperature. It appears that the intensity of a response to a change in temperature is increased if peripheral receptors as well as central receptors are stimulated. Keatinge (1969, p. 55) stated, "that although stimulation of skin receptors is necessary for a large metabolic response to cold, the size of the response is greatly increased by stimulation of deep receptors."

Effectors

The effectors are mechanisms of the body that respond to signals from the central nervous system and are capable of changing the temperature to maintain a central set-point temperature. The effector mechanisms include: changes in tissue insulation, changes in the amount of blood flowing through the blood vessels of the skin, alteration of muscular activity and sweat secretion.

Physiology of Immersion Hypothermia

The human body loses heat much more rapidly in water than in air. The thermal conductivity of water is approximately 26 times greater than air. Thus, during immersion heat is conducted away from the body to the surrounding water at 26 times the rate it is in air (Golden, 1973). An unclothed man immersed in cold water becomes largely dependent on internal mechanisms to limit this loss of body heat. The following section reviews the internal mechanisms and other physiological responses of humans in the defensive phase during cold water immersion.

Respiratory Responses

The initial shock of cold water immersion will produce hyperventilation with respiratory rates increasing to approximately five times the level of pre-immersion rest (Hayward, 1983). The hyperventilation response is greatest during the first couple of minutes, and by five minutes the

respiratory rate is reduced to a level more dependent on metabolic rate (Hayward, 1983). This response starts from the cold receptors in the skin which act directly on the respiratory control center.

The consequences of hyperventilation can be serious. The initial gasping response facilitates the breathing of water and thus, the possibilty of drowning. Hyperventilation also reduces the CO_2 of arterial blood which can lead to reduced cerebral blood flow resulting in clouding of consciousness and reduced swimming ability (Hayward, 1983).

Cardiovascular Responses

The primary physiological defense during exposure of the body to cold is peripheral vasoconstriction. This causes a reduction in the circulation of blood in the skin and as a result, heat loss to the environment is reduced. Boutelier (1979) reports that peripheral vasoconstriction is proportional to the intensity of cooling and

> . . . affects one, two, or all three arteriolar plexi; if cooling is more intense, even some of the muscular blood vessels are involved, particularly in such extremities as the hands, forearms, feet and legs (p. 34).

The effectiveness of peripheral vasoconstriction in reducing heat loss is further increased by counter-current exchange of heat between the arteries and veins that run side by side in the limbs. Boutlier (1979, p. 34) stated the effectiveness of counter-current heat exchange as

This veritable thermal "shunt" is a particularly

> effective mechanism; on the one hand, the arterial blood reaches the extremities at a low temperatue, so that the heat loss in the extremities is limited by the fact that the temperature difference between the extremities and the environment is reduced and, on the other hand, the gradual rewarming of the venous blood from the periphery reduces the cooling of the central parts of the organism.

Most of the heat loss from the body in moderately cold water therefore takes place from the trunk and not the limbs (Keatinge, 1969).

In very cold water (less than 10°C), cold induced vasoconstriction may be replaced by cold induced vasodilation due to the cold paralysis of the vascular smooth muscle (Hayward, 1983). This reaction is generally confined to the extremities and involves sudden bursts of vasodilation which brings a flow of warm blood to the extremities (Boutlier, 1979). However, this condition may be insignificant to increases in core cooling rate. Hayward (1983, p. 6) explains the possible effects of cold induced vasodilation as

> This condition is very obvious from the reddening of the skin of subjects during prolonged immersion in cold water. However, this author has not observed sudden inreases in core cooling rate commensurate with skin vasodilation. It is probable that constriction of deeper vessels in warmer tissues is being maintained such that skin blood flow is negligible despite skin dilation.

This rewarming of the skin appears to be considered a protective mechanism in the prevention of cold injuries to the skin (Leblanc, 1962).

In regards to other cardiovascular responses to cold water immersion, the heart rate, blood pressure, and car-

diac output are also affected. In the initial stimulatory phase, the heart rate increases dramatically and there is an increase in arterial pressure and cardiac output, accompained by intense peripheral vasoconstriction (Boutlier, 1979). Hayward (1983, p. 7) stated that "If immersion is prolonged until maximum shivering thermogenesis is attained, the heart rate of nonexercising subjects can rise as high as 130 to 140 beats per minute. However, as hypothermia becomes established, the heart rate and the cardiac output decreases simultaneously with the drop in body temperature (Boutlier, 1979). This cardiac reaction appears to have no effect on peripheral vasoconstriction, down to a rectal temperature of 25°C. Boutlier (1979, p. 63) stated

> Peripheral resistance shows an opposite change from that of the cardiac output, increasing as the body gets colder. However, if the rectal temperature fall below 25°C it decreases, showing that there has been failure of vasomotor tone.

Not only is there a failure of the vasomotor tone, but death due to cardiac arrest may also occur. Golden (1973, p. 80) stated "In humans, death due to cardiac arrest appears to occur between 24°C and 26°C, but there have been cases of accidental hypothermia surviving core temperatures of 18°C."

Metabolic Heat Production

Under basal conditions when no work is being done, all the metabolic energy appears as heat. During physical exertion more than 75 percent of the increased metabolism

appears as heat within the body, while the remainder of energy is converted to work (Best, 1979).

If an unclothed man is exposed to an environmental temperature below 28°C, a rise in heat production occurs. This rise in metabolic rate occurs primarily in the skeletal muscles, even before shivering is initiated (Best, 1979). During cold water immersion when shivering reaches its maximum at a core temperature of 35°C (Golden, 1973), the overall heat production may be as much as 4.5 times the resting rate (Hayward, 1983). Although shivering increases heat production, it also presents problems in conserving heat. Boutlelier (1979, p. 32) explains this phenomenon as

> The production of heat by shivering is not entirely beneficial. Indeed, rapid muscular shaking has the effect of disturbing the boundary layer of still water in the vicinity of the skin and, consequently, leads to an increase in the coefficient of heat exchange in water. In addition, shivering helps to maintain a higher temperature difference between the skin and the water than in the case of passive cooling and increases the losses by convection. Finally the increased oxygen consumption leads to an increase in ventilation and in the heat losses through the respiratory tract.

When the core temperature is between 27 and 30°C, the metabolic rate returns to a resting level (Golden, 1973).

Cooling Rate

If protection is not provided in water temperatures below 25°C, heat loss over-comes heat production and core cooling results (Hayward, 1983). The cooling rate of hu-

mans immersed in cold water is largely dependent on individual variation. The major factors that influence cooling rate are human differences (body size, body build, subcutaneous fatness, and shivering response) and behavioral effects (activity and posture). The following outline describes these factors.

Individual Differences

Body Size: Small body size has a greater surface area relative to volume. The greater relative surface area has an increased effect on core cooling rate. Thus, children tend to cool much faster than adults (Hayward, 1983).

Body Build: For any one body weight and fatness, ectomorphs have a greater surface area relative to volume and thus, cool faster than mesomorphs. (Hayward, 1983).

Subcutaneous Fatness: Extra amounts of subcutaneous fatness decrease core cooling rate.

Shivering Response: There are considerable differences (intensity and ability of maintaining a high metabolic level) among individuals in their shivering response to cold water. Good shiverers tend to cool more slowly (Hayward, Eckerson and Collis, 1974).

Behavioral Effects

Activity: During physical activity, blood circulation is increased to the arms, legs, and skin. This causes core cooling to be 35 percent faster than when the individual is holding still.

Posture: In a curled-up position, (arms against the chest and the thighs against the chest) the core cooling rate can be reduced by a significant amount.

Design Concepts

There are basic recurring design features in most anti-immersion suits. The primary feature is whether the suit is "dry" or "wet"; that is, whether or not water is allowed within the suit. Dry suits provide complete watertightness and insulation. This usually involves the use of a waterproof zipper, neck seals and wrist seals. The wet suits are not watertight but retain suitable insulating properties. The wet suits involve the use of neoprene foam. The dry and wet suit categories can be further subdivided into the following subgroups:

1. Dry suits with little insulation
2. Dry suits with foam-rubber insulation
3. Dry suits with air-space insulation
4. Wet suits covering entire body
5. Wet suits covering partial body

In regard to protection, "dry foam" and "dry air" suits were found to be categorically superior to dry suits and wet suits (Harnett, O'Brien, Sias, and Pruitt, 1979). Also by category, it can be generalized that wet suits are superior to dry suits (Hayward, 1978). The dry suits' ineffectiveness is due primarily to the compression by water which can reduce insulation by 75 percent (Goldman,

Breckenridge, Reeves, and Beckman, 1966). The wet suits' effectiveness is a result of the insulation of clothing made of closed cell foam neoprene. Laboratory studies on 1/8 inch closed cell neoprene have indicated that compression at a water depth of 2 1/2 feet, would only be 2/1000 of an inch (Beckman, 1963).

Other information for consideration in the design of protective clothing include the findings from the following studies: (1) a study using infrared pictures has indicated that the lateral thorax, the upper chest and back, and the groin area are the major heat loss areas during immersion (Hayward, Collis, and Eckerson, 1973); (2) a study by Reins and Shampine (1972) has indicated that the fit of a suit is important because 23 percent of heat loss is due to flushing of water in and out of the suit; and (3) a study by Rasmussen and Steen (1983) has found that the donning performances by subjects using an experimental model (sleeveless jacket style boating device) were significantly better than for those using a Technical Standard Order (TSO) certified personal flotation device.

CHAPTER III

MATERIALS AND METHODS

This chapter describes the design development, selection of the sample, experimental design, instrumentation procedures, calibration of equipment, experimental protocol, test conditions and the data analysis used in the study. The objectives of the research were to develop a prototype life preserver that met the FAA specifications, to test and evaluate the thermal response characteristics of human subjects wearing the prototype life preserver and a currently used standard personal flotation device, and to estimate a predicted survival time for human subjects wearing the prototype life preserver and a currently used standard personal flotation device.

Design Development

The design process consisted of a review of literature, a material search, development of designs, and a preliminary evaluation of universal sizing, donning, bouyancy, and self-righting characteristics of the prototype life preserver. A convenience sample of OSU students and FAA personnel were used for the preliminary evaluation of the prototype life preserver.

Material Search

Information as to the type of materials and closure devices used in cold weather survival gear was obtained when doing the review of literature. Typical materials and closure devices consisted of: waterproof fabrics, closed cell neoprene, waterproof slide fasteners, conventional zippers, goose down feathers, fiberfill insulation, and thinsulate insulation. Manufacturers were then contacted by letter (Appendix A) and/or telephone to obtain a sample of the various materials and closure devices.

Development of Designs

In the development of the design for the prototype life preserver, consideration had to be given to all six specifications required by the FAA. Taking all the specifications into account simultaneously, added to the complexity of the design problem.

The first step in the design procedure was to determine which specifications limited the amount of thermal protection that could be provided. The following four specifications were identified:

1) The life preserver should be capable of being donned by an adult in fifteen seconds

2) The life preserver should meet the airlines' weight and storage specifications

3) The life preserver should fit individuals from the

5th percentile of adult females to the 95th percentile of adult males in the United States population

4) The life preserver should self-right the wearer in five seconds

The most limiting specification was that the life preserver should be capable of being donned by an adult in fifteen seconds. This specification and the weight and storage requirements (specification 2) deleted any consideration af a full protection suit. Thus, to allow for ease of donning and yet provide thermal protection, attention was focused on a life preserver that covered the upper torso area.

The current standard personal flotation device is a dual-chamber air bladder that is U-shaped and encompasses only the neck area. Complicated retention harnesses are used to secure the life preserver to the body (Figures 1 through 3). The current standard personal flotation device meets the weight and storage requirement, but does not provide thermal protection or allow for ease of donning. A study by Rasmussen and Steen (1983) found that the mean donning time for the currently used life preservers ranged from 28 to 37.6 seconds.

The study by Rasmussen and Steen (1983) also found that the mean donning time of experimental models (sleeveless jacket style boating devices) ranged from 15.8 to 16.8 seconds. Therefore, to allow for ease of donning, an air bladder was designed as a jacket style bladder (Figures 4 through 6) with a conventional wide tooth zipper positioned

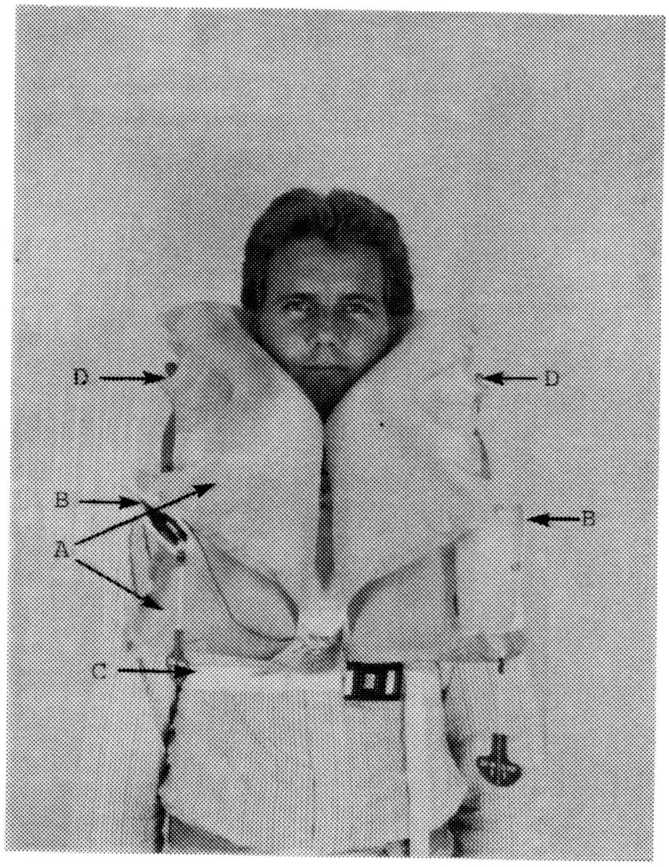

Figure 1. Standard Personal Flotation Device (Front View)
A. Dual chamber air bladder
B. Two 16 gm. CO_2 cylinders
C. Adjustable waist strap
D. Oral inflation tubes

Figure 2. Standard Personal Flotation Device (Side View)
A. 16 gm. CO_2 cylinder
B. Oral inflation tube

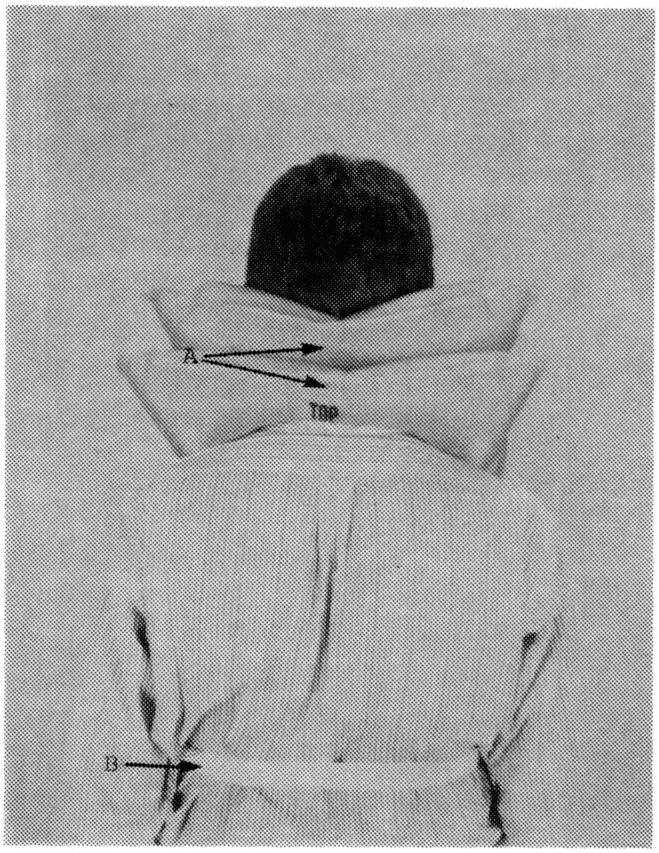

Figure 3. Standard Personal Flotation Device (Back View)
A. High inflatable collar for support of head and neck
B. Waist strap

Figure 4. Prototype Life Preserver (Front View)
A. Single chamber air bladder
B. One 28 gm. CO_2 cylinder
C. Oral inflation tube
D. Front zipper
E. Heat sealed areas
F. Belt

Figure 5. Prototype Life Preserver (Side View)

Figure 6. Prototype Life Preserver (Back View)
A. High inflatable collar for support of head and neck
B. Closed cell neoprene

down center front for a closure device. The jacket style design was chosen for the sake of simplicity and familiarity so that passengers would instinctively know how to don the life preserver.

A water-proof zipper (open on both ends) was considered at this time in place of the conventional zipper. However, this design concept was deleted due to the difficulty of getting the zipper together. Unlike conventional zippers, the water proof zipper had to be turned to the inside before it could be fastened at the bottom. Another disadvantage of the water-proof zipper was the additional cost.

The second limiting specification was the airline's weight and storage requirement. One of the currently used personal flotation devices weighs approximately 1 pound 8 ounces. Typical airline storage space for one life preserver is approximately 5.5 inches wide, 7 inches tall and 3.25 inches deep. The total storage space is equal to 129 cubic inches. Figure 7 illustrates the comparison in packaging for the prototype life preserver and the standard personal flotation device.

Due to the limited weight and storage space requirements, consideration was given to lightweight materials and closures devices which had the ability to be folded compactly, yet provide thermal protection. Polyurethane-coated nylon was used for the air bladder portion of the prototype life preserver. Heat sealing equipment was used to bond the polyurethane film together which provided for

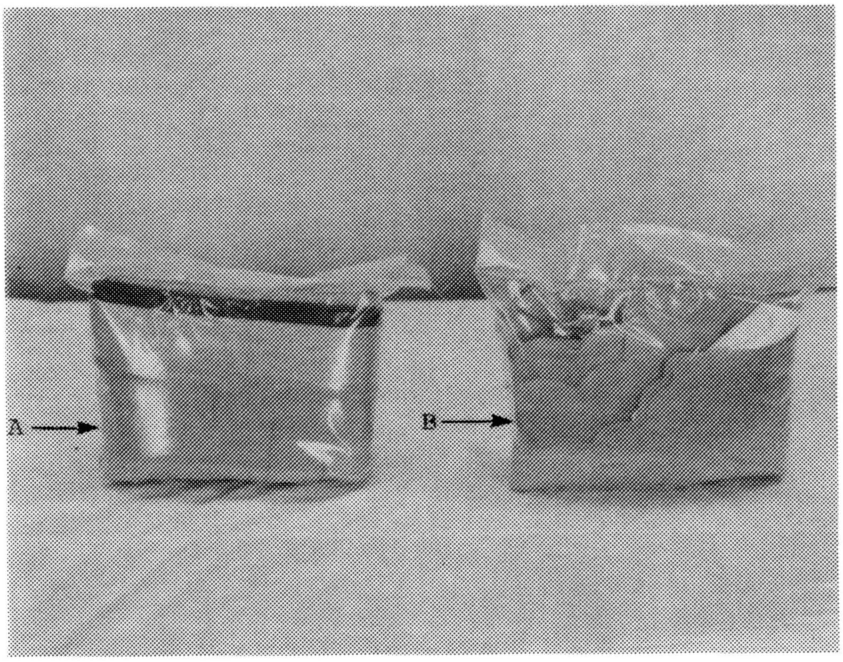

Figure 7. Package Comparison
A. Prototype Life Preserver
B. Standard Personal Flotation Device

an air tight bladder. A light-weight conventional zipper was used for a closure device. One-eighth inch closed cell neoprene was used in the lower back region.

In addition to using lightweight materials and closure devices, the jacket style air bladder was designed so that the major heat loss areas of the upper torso were protected. Studies using infrared pictures (Hayward, 1973) have indicated that the upper chest and back, sides of the chest, lateral thorax, and the groin area are the major heat loss areas during immersion. Protection for the groin area was not considered due to additional weight and storage space and the extra time that would be required to don the life preserver. The air held within the bladder appeared to be a conceivable way of providing insulation without adding additional weight or storage space.

Another design concept developed at this time used the same style of air bladder, but filled with goose down feathers to further improve the insulation value. Goose down feathers were considered due to their high insulation value and compressibility. However, from a manufacturing viewpoint, this design concept was deleted due to the difficulty of keeping the feathers inside the air bladder during the production process. Another disadvantage of the goose down feathers was the additional cost.

The third limiting specification was that the life preserver should fit individuals from the 5th percentile of adult females to the 95th percentile of adult males in the United States population. Studies by Reins and Shampine,

(1972) found that thermal protection was significantly increased when a suit provided a close fit to the wearer's body. Thus, the objective in mind was to provide universal sizing and to provide a close fit for the majority of the designated population.

To achieve universal sizing, one-eighth inch closed cell neoprene was attached to the air bladder in the lower back region (Figure 6). The 300 percent stretch of the closed cell neoprene allowed for universal sizing. For durability, the one-eighth closed cell neoprene has a tensile strength of 60 pounds per square inch.

To achieve a close fit for 90 percent of the population, anthropometric data (Churchill, Laubach, McConville, and Tebbetts, 1978) for males and females were used to specify critical measurements. The body measurement for the chest of the 95th percentile male was chosen as one guideline for sizing of the prototype. To illustrate the measurement range for males and females in the designated population, the 95th percentile male chest measurement was 10.8 inches larger than the 5th percentile female chest measurement. However, the chest measurement of the 95th percentile male provided a close fit for the 5th percentile adult female since the prototype greatly contracted in the chest area when inflated. The 300 percent stretch of the closed cell neoprene in the lower back region achieved a close fit for the 95th percentile adult male.

Another guideline for sizing of the prototype life

preserver was the waist measurement of 38 inches. This measurement was 14.6 inches larger than the 5th percentile adult female and 1.6 inches smaller than the 95th percentile adult male. A large waist measurement of 38 inches was chosen primarily to enhance the ease of donning for the large individuals in the designated population. When inflated, the prototype life preserver contracted approximately three inches in the waist circumference measurement. To provide a better fit and restrict water entry for small adults, a belt which could be cinched was attached to the lower part of the prototype life preserver. The belt was also needed to maintain the bladder tight against the body during immersion. To achieve a close fit for the 95th percentile adult male, the closed cell neoprene in the lower back region provided ample stretch.

A problem encountered early in the design development was that the rough side of the closed cell neoprene would cling to the body and not stretch to its full potential. To correct this problem, the closed cell neoprene was turned so that the skin side was next to the body.

The other method of providing a close fit for 90 percent of the population involved the proper location of heat sealed areas on the bladder (Figures 4 and 6). By heat sealing the polyurethane-coated nylon in desired areas, the air could be positioned to provide the desired amount of air in the areas where fit was critical. Extensive design modification work was done to position the air so that the air bladder would remain close to the body in

the neck and armhole areas, thereby restricting water entry and water movement within the preserver.

The fourth limiting specification was that the life preserver should self-right the wearer in five seconds. To achieve the self-righting function, the majority of air had to be positioned above the wearer's center of gravity. The center of gravity is different for each individual due to differences in body build, body size and body fat. Thus, to achieve the self-righting function, the small female was considered in determining how high the air should be positioned on the chest. Consideration was also given to the larger male who required a large amount of air in the chest area. A large air mass in the chest area caused the life preserver to bulge away from the body; this also allowed a larger quantity of water inside the life preserver than was desired. However, the large air mass in the chest area helped achieve the self-righting function.

The heat sealed areas mentioned earlier also served to position the large air mass in the upper portion of the chest. The heat sealed diagonal lines on the lower portion of the life preserver (Figure 4) helped to pull the vest closer to the body. Extensive time was devoted to achieve the self-righting function and yet provide a close fit to the body.

Selection of the Sample

The population consisted of ten paid volunteer male

subjects, aged 18 to 35 years. A cutoff point of age 35 was arbitrarily chosen to increase the likelihood of good health and physical condition. Table I describes the characteristics of the subjects. To increase the chances of the subjects completing both tests, the selection of the sample was focused on subjects who had scuba diving training or on subjects who might need to enter cold water due to their profession. Three subjects were solicited from the Oklahoma City Fire Department (water rescue team), four subjects from the Oklahoma State University Scuba Club and three subjects from the general public. Two subjects from the general public had no scuba diving training. All subjects were acquired through the FAA subject contractor.

Each subject gave his informed consent (Appendix B) to participate after being familiarized with all the procedures and purposes of the experiment (Appendix C). The study was conducted according to the principles of the Civil Aeromedical Institute (CAMI) Human Research Review Committee. The safety criteria required that no subject be on any medication. In addition, subjects were required to pass an FAA Class 2 medical examination given by a FAA physician. This examination required a medical history (Appendix D), a physical examination (Appendix E), and the donation of blood and urine for analysis.

After passing the physical exam, the subject proceeded to the survival tank to participate in a trial test. The subject inserted a rectal thermistor probe approximately 10 cm (4") for the measurement of internal body temperature.

TABLE I

SUBJECT CHARACTERISTICS

Subject	Age (years)	Weight (kg)	Height (cm)
JA	31	97.7	180.3
PP	18	90.0	180.3
MS	30	87.7	177.8
KB	25	93.6	180.3
OB	26	75.0	167.6
BP	24	74.5	177.8
MJ	22	74.1	188.0
AR	23	63.2	175.3
KT	23	65.9	167.6
GR	33	72.7	182.9

The subject was also instrumented with adhesive chest electrodes (Figure 8) to which wires were connected for the recording of heart rate and electrocardiogram (EKG). After instrumentation was completed, the subject donned the standard personal flotation device or the prototype life preserver and then entered the water for a 15 minute period. This test was to reduce the learning effect and to determine whether or not the subjects were willing to participate in the study. If the subject passed the medical examination and was willing to participate, the tests were then scheduled.

Experimental Design

Table II outlines the experimental design for this study. Two subjects were tested at one time. Two positions in the pool were selected to ensure that both subjects were equal distances from the water current generated by the inlet ports. The standard personal flotation device was assigned to Position 2 and the prototype life preserver was assigned to Position 1. Each subject wore the prototype life preserver in one experimental test and the standard personal flotation device in another experimental test on two separate days. At least one day was allowed to elaspe between the two experimental tests. The standard personal flotation device and the prototype life preserver were tested the same day. This procedure reduced the differential effects on deep body temperature caused by day to day differences in environmental conditions. All sub-

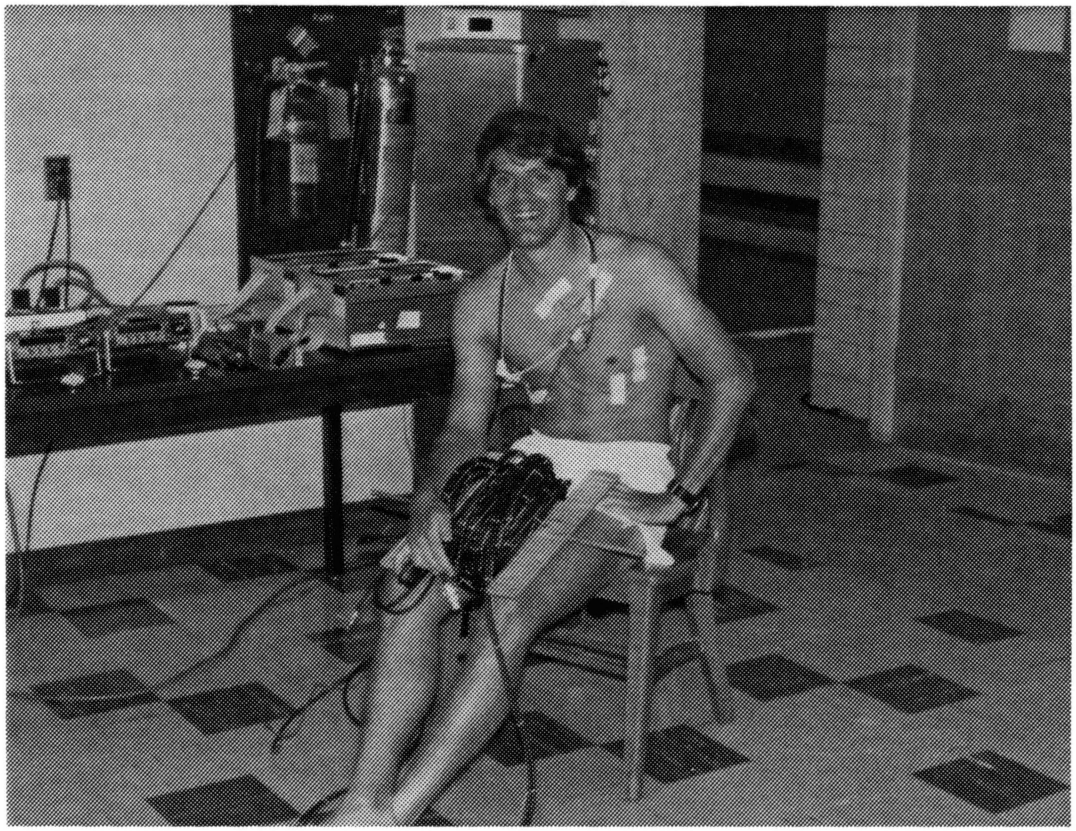

Figure 8. Subject Instrumented with Adhesive Chest Electrodes

TABLE II

RESEARCH DESIGN

Experiment Number	Tank Position 2	Tank Position 1
1	S_1/V_1	S_2/V_2
2	S_2/V_1	S_1/V_2
3	S_3/V_1	S_4/V_2
4	S_4/V_1	S_3/V_2
5	S_5/V_1	S_6/V_2
6	S_6/V_1	S_5/V_2
7	S_7/V_1	S_8/V_2
8	S_8/V_1	S_7/V_2
9	S_9/V_1	S_{10}/V_2
10	S_{10}/V_1	S_9/V_2

Legend: S_1 represents subject 1, S_2 represents subject 2, etc.; V_1 represents the standard personal flotation device, V_2 represents the prototype life preserver.

jects wore standard cotton shorts and athletic supporters during the tests.

Instrumentation

The subjects were fitted with three adhesive chest electrodes (Beckman Well Electrodes, Ag/Ag Cl, Beckman Instruments, Inc., Fullerton, CA 77036) to which wires were connected for the recording of heart rate and EKG. The CM5 single lead was used to monitor EKG function. The EKG cable was connected to remote monitoring and recording equipment. The EKG was monitored on an electrocardiograph (Burdick EK-5A, The Burdick Corporation, Milton, Wisconsin) and simultaneously recorded on a polygraph (Grass Polygraph, Model 7, Grass Instrument Co., Quincy, Mass.). The heart rate was also monitored on a heart rate meter which averages every four beats (Burdick CSS - 61, The Burdick Corporation, Milton, Wisconsin).

Subjects were required to insert a rectal thermistor probe (Yellow Springs Instrument 701) inside the rectum, approximately 10 cm (4") for the measurement of internal body temperature. The temperature readings were displayed on a 3-probe LED digital thermistor thermometer °F (Digitec HT Series, Model No. 5820, United Systems Corporation, Dayton, Ohio) and recorded every two minutes. Data recording sheets used for recording rectal temperature and heart rates are given in Appendix F.

A BIO-TEK analyser (BIO-TEK Instruments Inc., Burlington, Vermont) was used to check the equipment to assure

that the hazard of electrical shock to the experimental subjects was within acceptable limits. The inspection forms are included in Appendix G.

Calibration of Equipment

Each rectal thermistor probe was calibrated using a constant temperature water bath (Haake, PolyScience Corporation, Evanston, Illinois). The accuracy of the instruments were +-.7°F of the digital reading after calibration.

Experimental Protocol

Subjects were instructed to refrain from eating between midnight of the preceeding day to the end of the test period. This minimized the variation in blood glucose levels. Subjects reported for their test session at 8:15 AM. The tests began at approximately 9:00 AM. Performing the tests at the same time each day minimized the differential effects on deep body temperature caused by usual daily variation.

When the subjects reported at 8:15 AM, they were briefly examined by a physician to insure that their physical condition had not changed. The physician checked for interim changes in health status (Appendix H). Blood pressure, pulse and oral temperature were taken. If no changes in their physical condition were detected, they then proceeded to the survival tank where they were instrumented as during the trial test.

After instrumentation was completed the subjects entered the water. Each test exposure lasted for two hours or until any of the following conditions applied: (A) an internal body temperature of 35°C (95°F); (B) an electrocardiographic abnormality; (C) request by the subject; or (D) discretion of the physician. The behavioral activity during exposure was limited to minimal physical activity. The subject adopted a face-up, flotation position (Figures 9 and 10).

While in the pool the subjects were tethered and each had his own individual observer. A physician, a lifeguard and a video technican were always in attendance during the tests. A team of support personal were also in attendance to monitor and record heart rate, EKG, and rectal temperature. When the tests were completed, the subjects were brought out of the water on a stretcher. The vests were quickly removed and then the subjects were taken to an adjacent room where assistance was provided on removing the wet shorts and putting on the sweat suits. During the changing of the garments, the rectal thermistor probe remained inserted. When the changing was completed, the subjects were taken to a warm room where they remained until their internal body temperature reached 36.5°C. During this time they were provided Gatorade® to drink. When the internal body temperature reached 36.5°C, they were then allowed to take a warm shower.

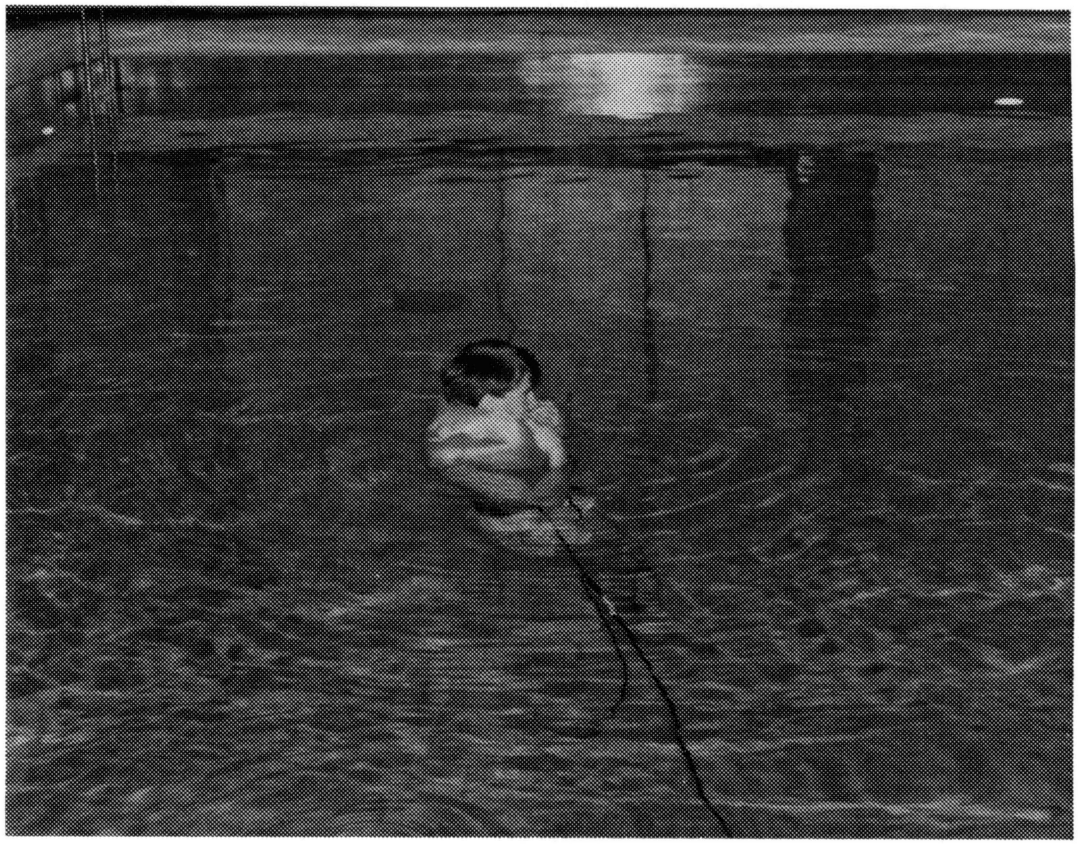

Figure 9. Subject Demonstrating a Face-Up Flotation Position While Wearing the Prototype Life Preserver

Figure 10. Subject Demonstrating a Face-Up Flotation Position While Wearing the Standard Personal Flotation Device

Test Conditions

During the period of study, the water temperature was 12.8°C (55°F) +- .5°C and the air temperature was 21.1°C (70°F) +- 1.7°C. The variation in water temperature throughout the pool was held within .75°F. The water temperature of the pool was measured periodically on all four sides and at various depths. The water temperature was measured with a rectal thermistor probe (Yellow Springs Instrument 701). The temperature readings were displayed on a digital thermistor thermometer. The accuracy of the thermometer was +-.7°F. The air temperature was measured with an air temperature probe (Yellow Springs Instrument 705). The air temperature readings were displayed on a direct-reading thermistor thermometer. The accuracy of the thermometer was +-.1°F.

Data Analysis

The subject's rectal temperature for each vest was graphed over time. Each subject's rectal temperature was measured and recorded every two minutes. Least squares regression was used to fit the data to a straight line for determining the slope from which a cooling rate per hour was established. A paired t-test was used to determine significant differences between cooling rate for subjects wearing the two vests. Differences were accepted at the .05 level of confidence.

To determine the rate of cooling, a "linear model" was

adopted for this study which involved two parameters: the time (t) that internal body cooling was established at fairly uniform rates for all subjects (20 minutes) and the rate of cooling (r) following this time. The rate of cooling was the slope of the regression line which was determined from data points obtained at t (20 minutes) to the last data point recorded.

Hayward's (1975) formula was used with the cooling rate data to estimate predicted survival time (pst). It must be noted that the predicted survival time estimates are based on the assumption that the linear cooling rates established during the experimental tests would continue until a lethal level is reached. In this study, estimates of predicted survival time for two rectal temperatures (34.4 and 30°C) were determined based on Hayward's (1975) equation:

$$pst_{12.e} = (t - \text{lethal temperature})/r + 20$$

where t is equal to the subject's rectal temperature at 20 minutes; r is equal to the subject's rate of cooling. Twenty minutes was chosen as the time interval after which all the subject's rectal temperatures appeared to show a fairly uniform rate of decline.

Each subject's heart rate was recorded continuously on an EKG polygraph. Recorded heart rates were counted using the EKG polygraph at the 5, 10, 20, 30, and 40 minute intervals. Recorded heart rates were also counted during the last four minutes of each subject's immersion test when the rectal temperature was expected to be minimal. A paired t-

test was used to determine significant differences between subjects' heart rates while wearing the two vests. Differences were accepted at the .05 level of confidence.

CHAPTER IV

RESULTS AND DISCUSSION

Chapter IV presents results and analyses of the data obtained during the cold water immersion tests. Findings are discussed.

The complete rectal temperature-immersion time profiles are shown graphically for each immersion in Figures 11 through 20. These graphs illustrate the changes in rectal temperatures as functions of elapsed immersion time. Graphs showing the absolute rectal temperature over time are presented in Figures 21 through 30 (Appendix I). Separate graphs are presented for each subject. Each graph includes the two experimental tests completed by each subject. The standard personal flotation device is labeled as Vest 1 and the prototype life preserver as Vest 2. Out of the 20 immersion tests, five immersions were terminated early due to cramps, gastrointestinal discomfort or on the subject's request. One of the twenty immersions had to be terminated early due to loss of the EKG signal. In general, rectal temperature dropped with increased time in the cold water. The rate of decline appeared approximately linear after 20 minutes of exposure.

The results of the cold water immersion tests are

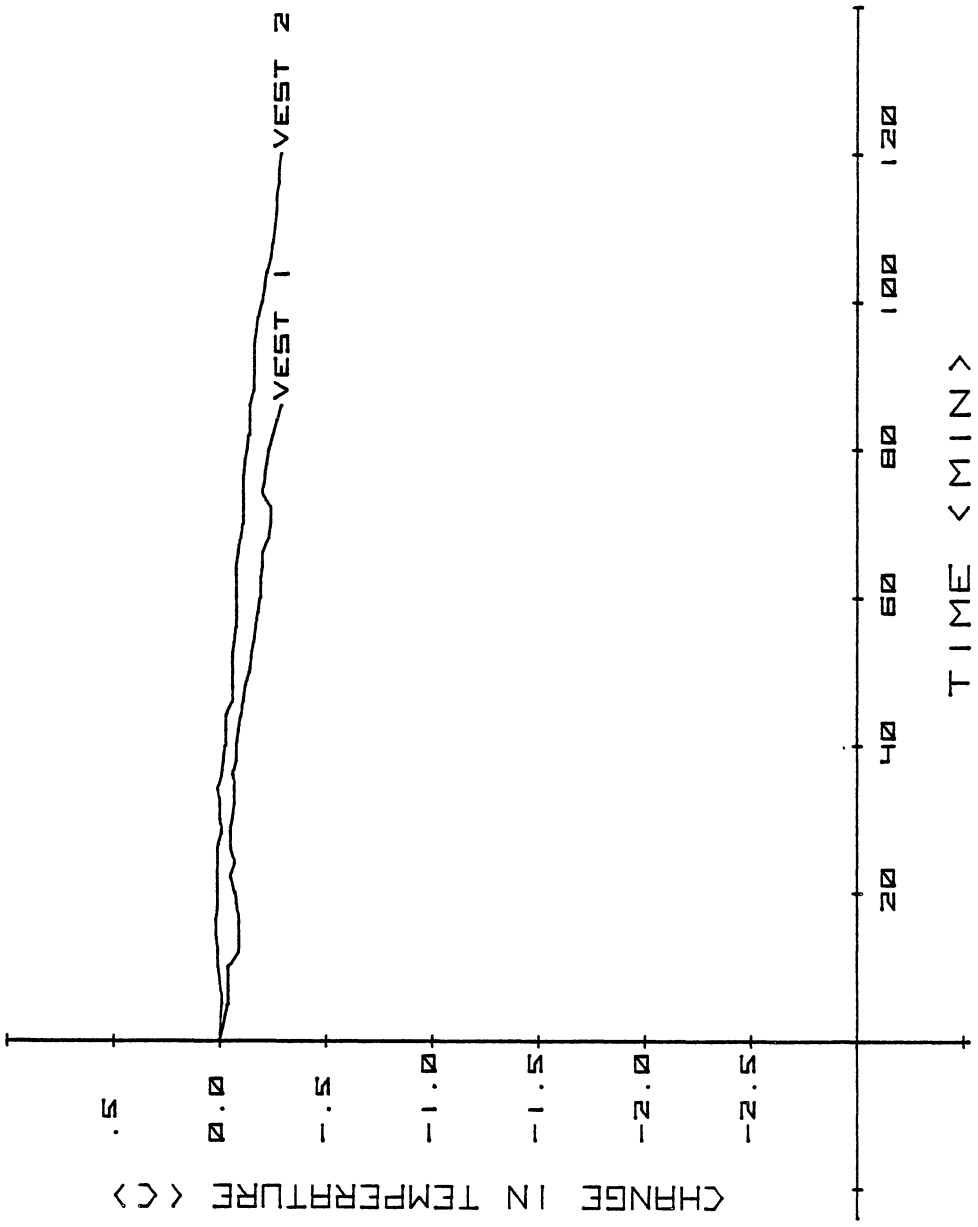

Figure 11. Change in Rectal Temperature Over Time During Immersion for Subject JA

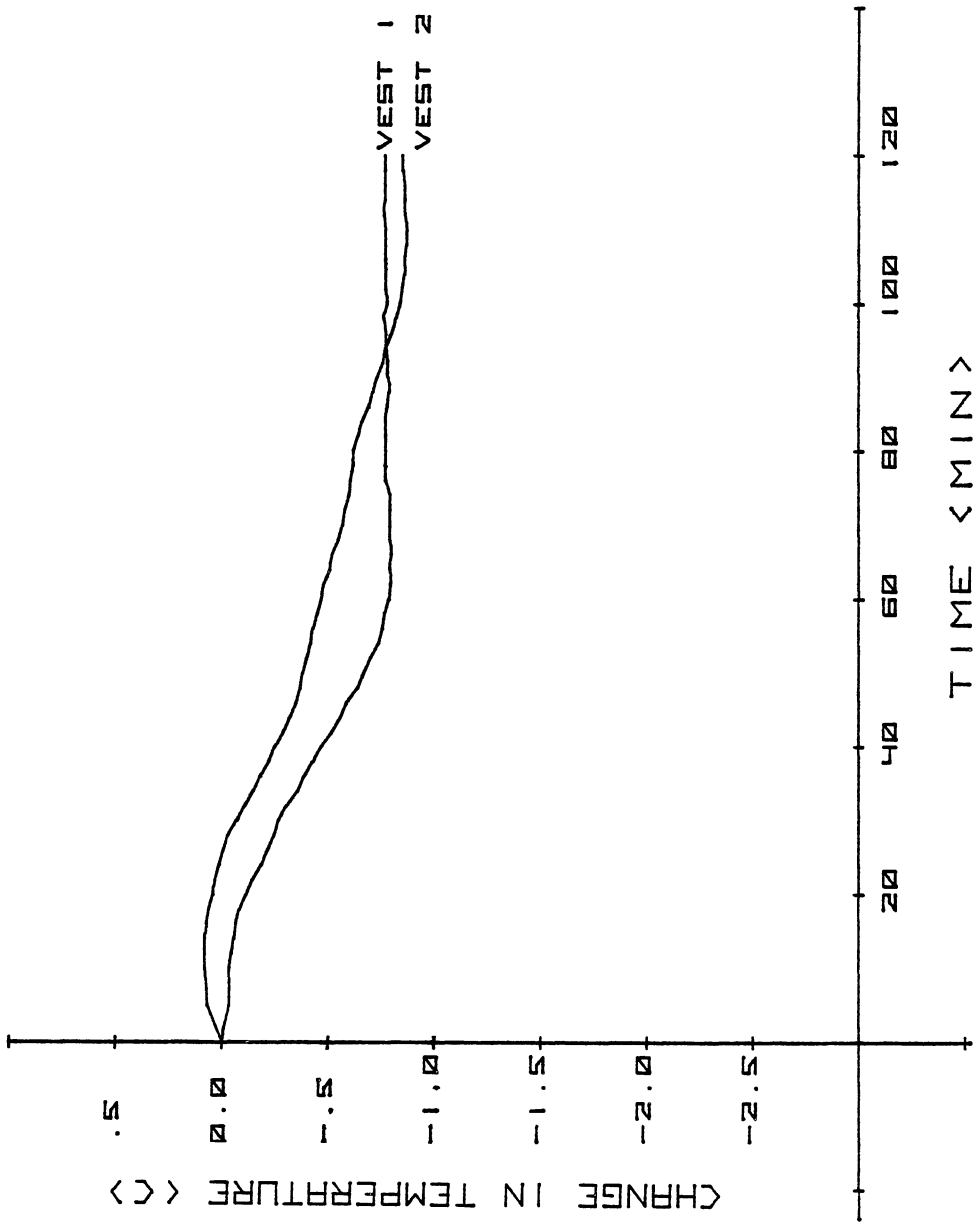

Figure 12. Change in Rectal Temperature Over Time During Immersion for Subject PP

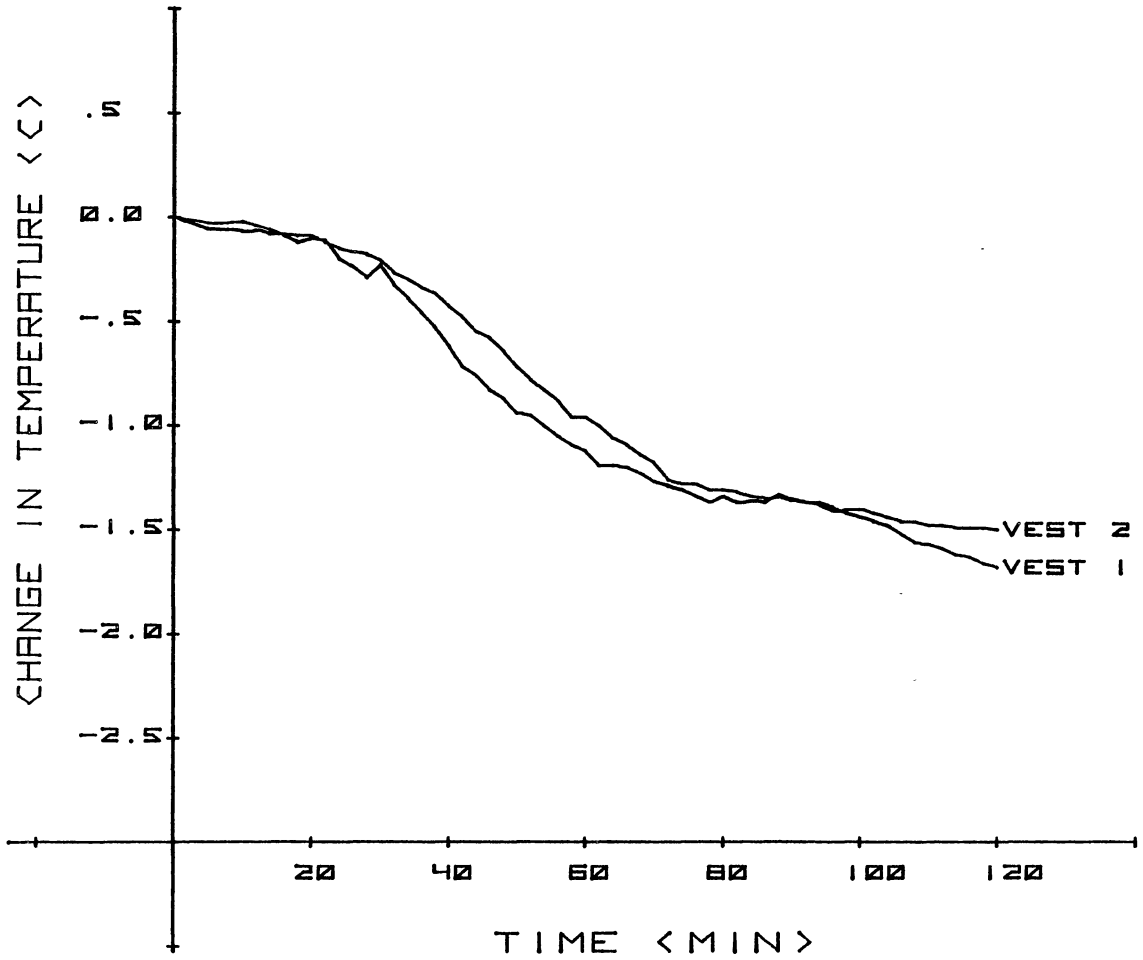

Figure 13. Change in Rectal Temperature Over Time During Immersion for Subject MS

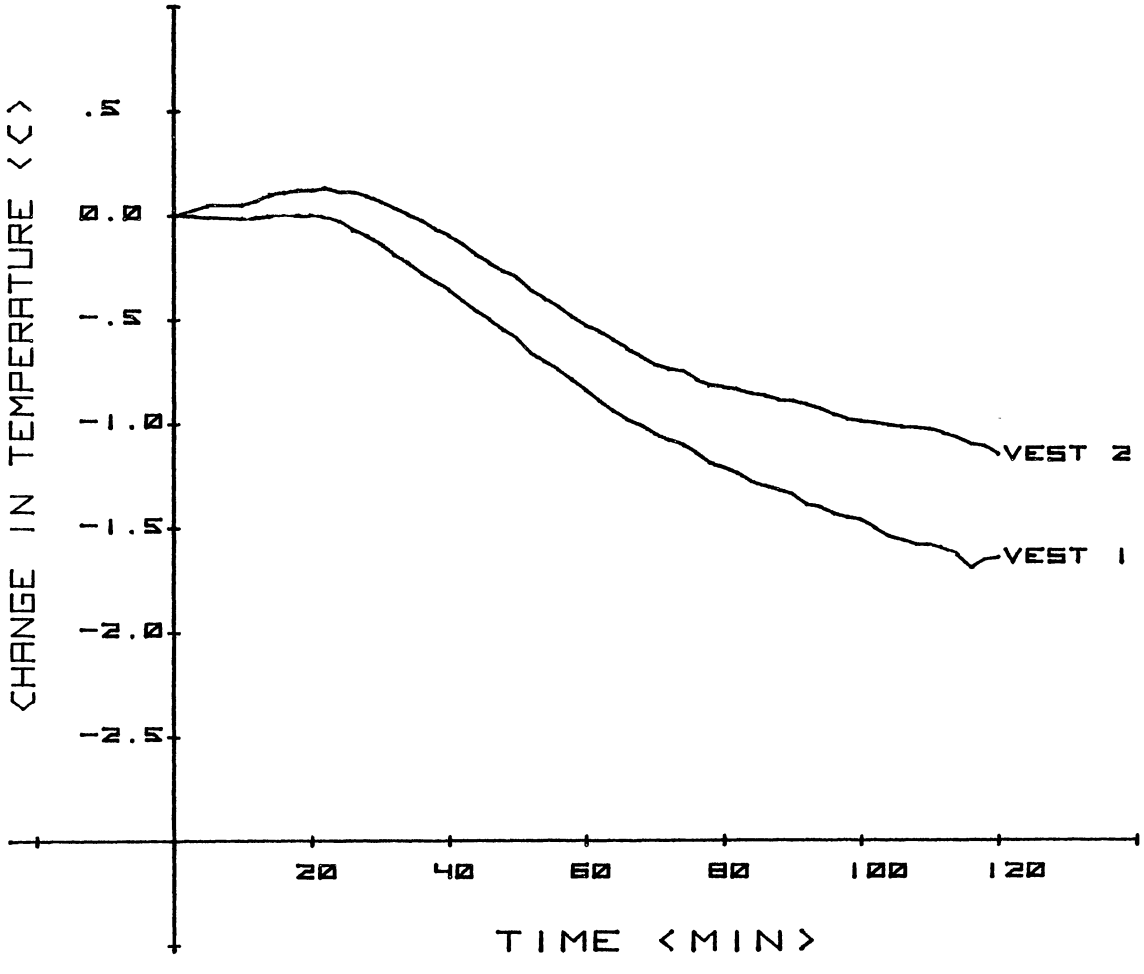

Figure 14. Change in Rectal Temperature Over Time During Immersion for Subject KB

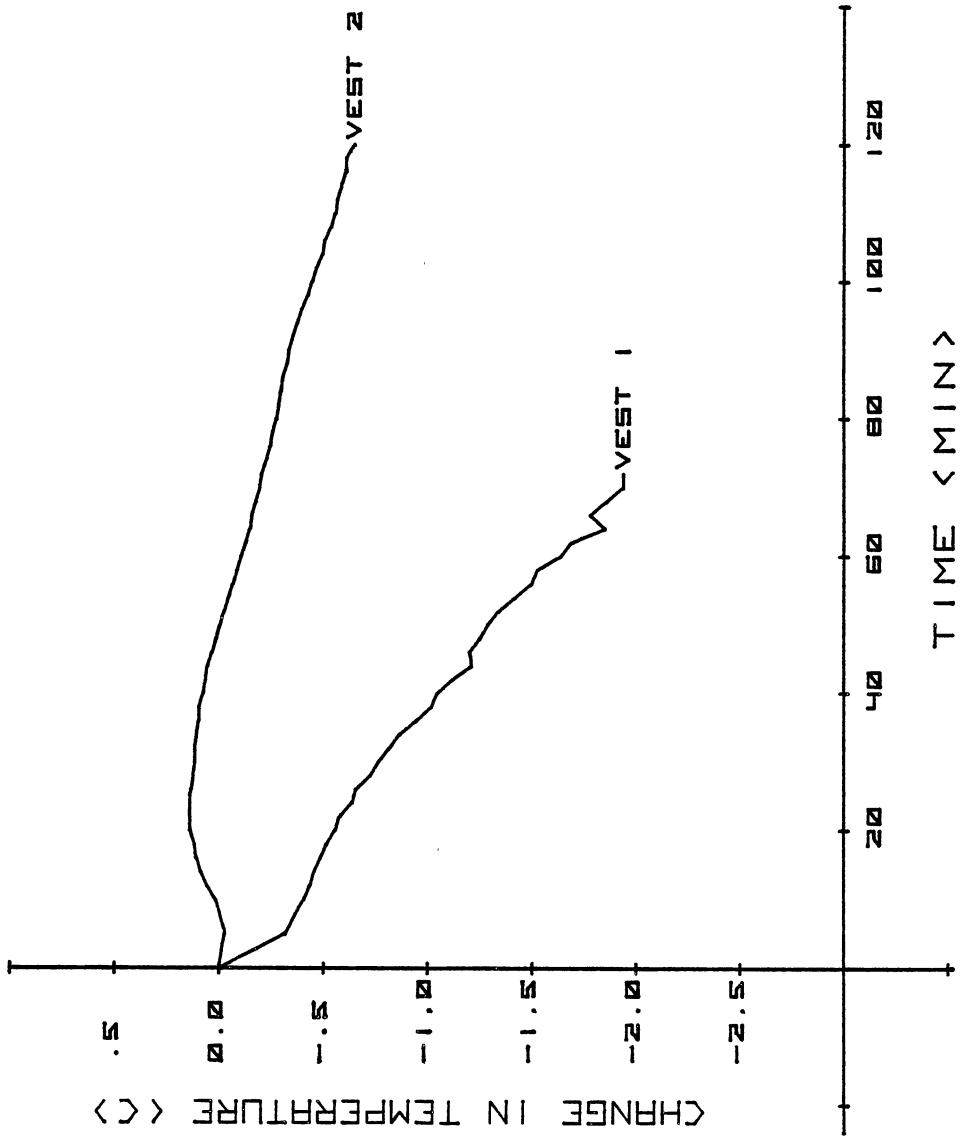

Figure 15. Change in Rectal Temperature Over Time During Immersion for Subject 08

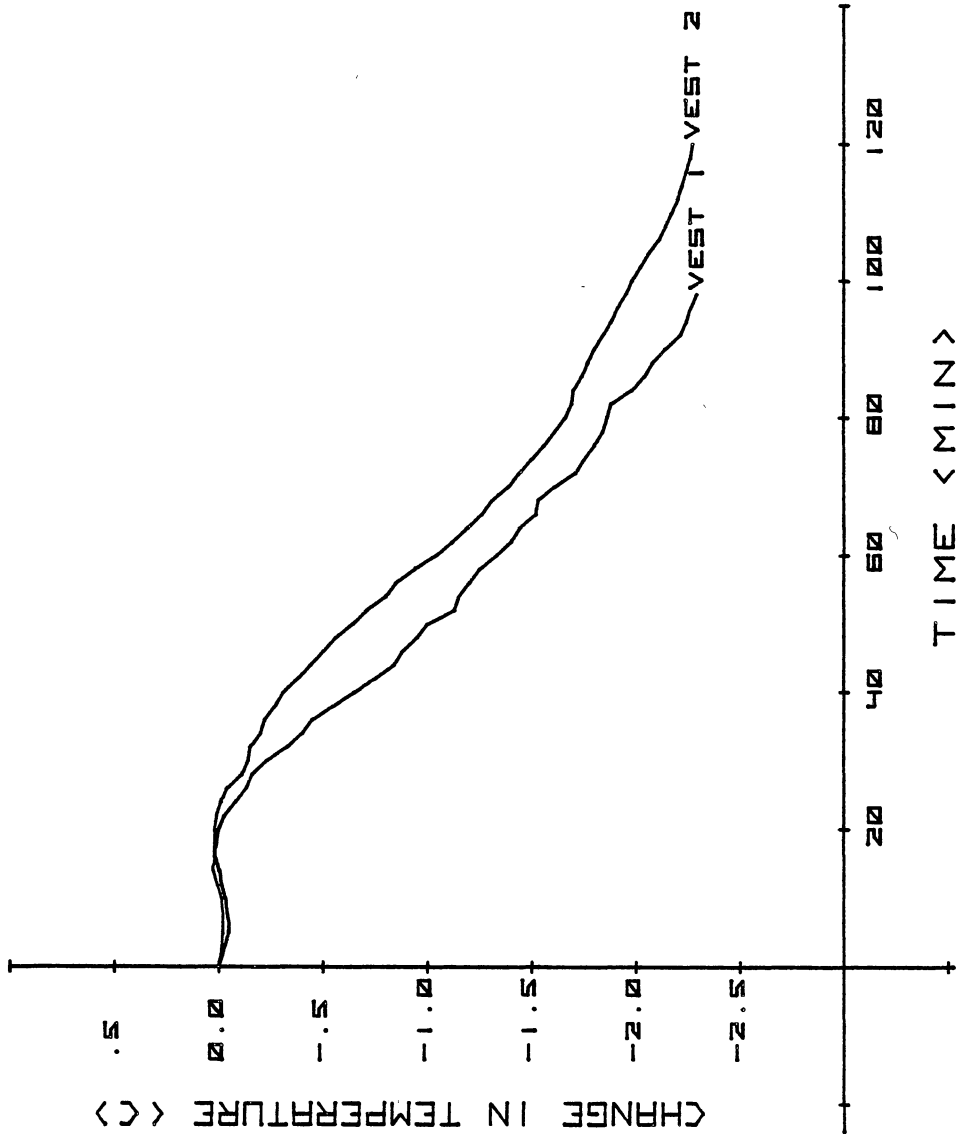

Figure 16. Change in Rectal Temperature Over Time During Immersion for Subject BP

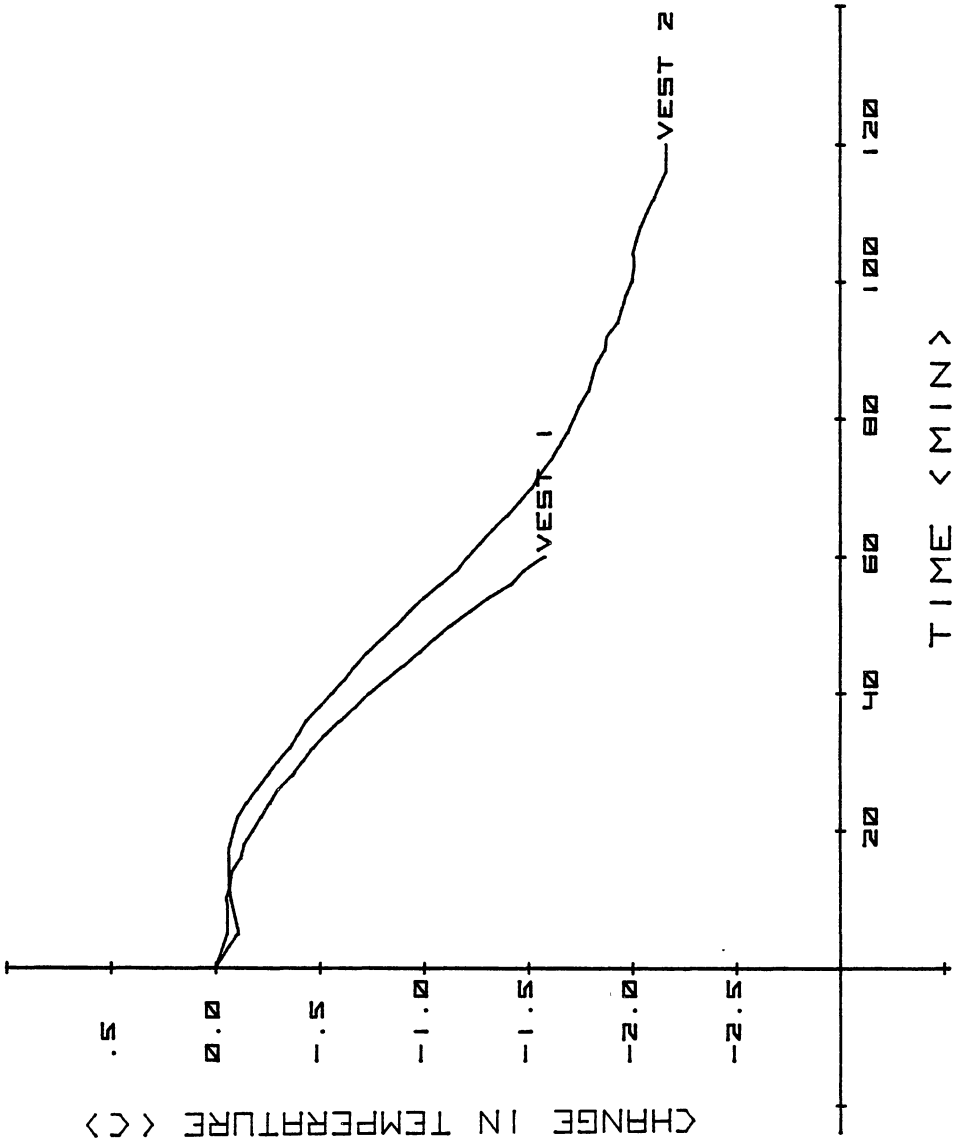

Figure 17. Change in Rectal Temperature Over Time During Immersion for Subject MJ

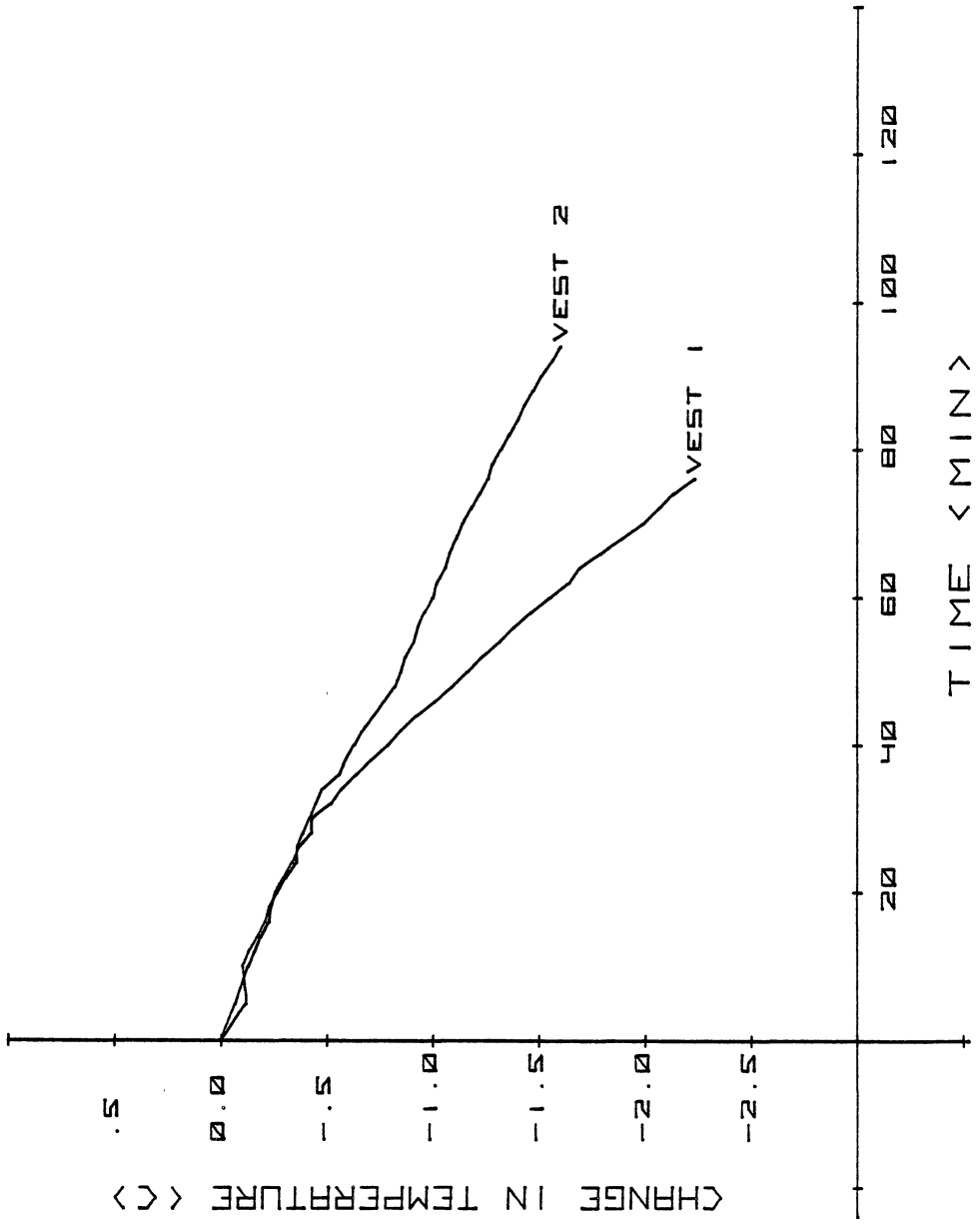

Figure 18. Change in Rectal Temperature Over Time During Immersion for Subject AR

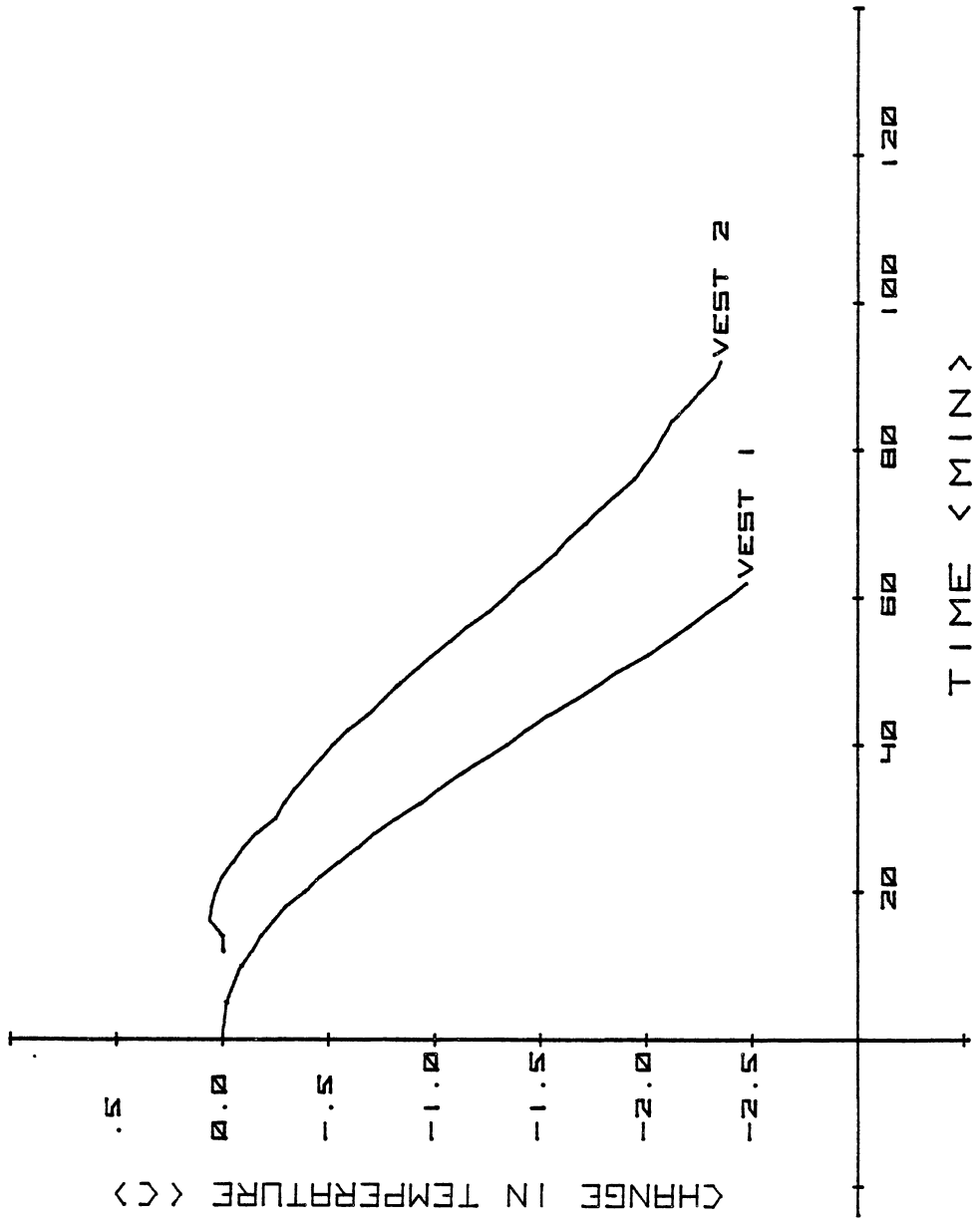

Figure 19. Change in Rectal Temperature Over Time During Immersion for Subject KT

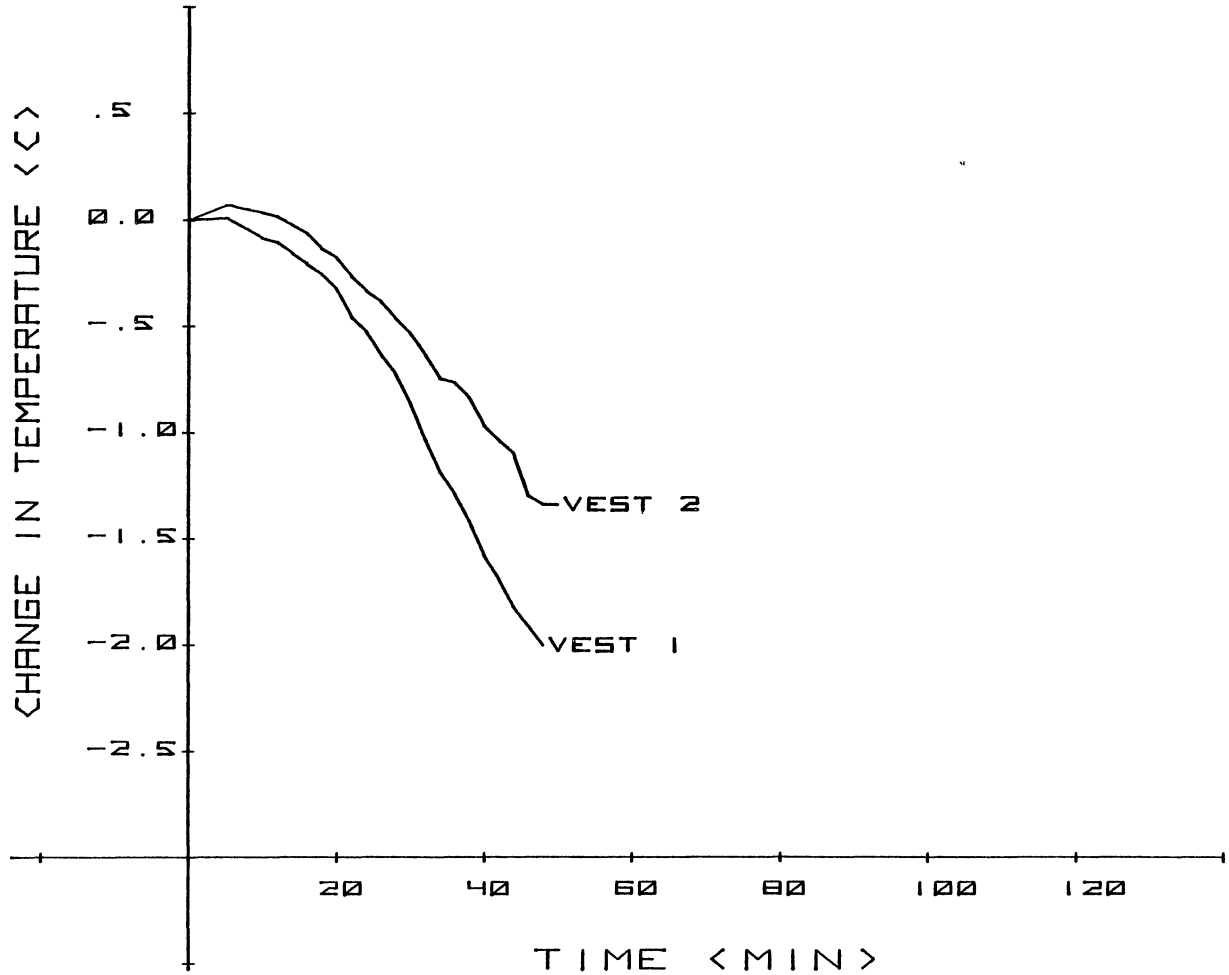

Figure 20. Change in Rectal Temperature Over Time During Immersion for Subject GR

summarized, in terms of the cooling rate per hour, in Table III. The means and standard deviations are shown for each type of design. Regression correlation coefficients are presented for each subject's rate of cooling by design. Percentage of improvement in cooling time with the prototype life preserver is presented for each subject. As data in the table show, the mean cooling rate of subjects wearing the prototype life preserver (1.15°C/h) was lower than when the same subjects wore the standard personal flotation device (1.72°C/h). Differences in cooling rate were statistically significant at the .05 level. Regression analysis shows that there is a high degree of correlation between the immersion time and the change in rectal temperature. Eight out of ten subjects while wearing the prototype life preserver showed a decrease in the rate of cooling over the standard personal flotation device.

In order to further evalute the practical significance of increased thermal protection, the cooling rate data of the present study were used to predict durations to "lethal" levels of hypothermia for water near 12.8°C. What constitutes a "lethal" level of hypothermia has been a matter of controversy among researchers. Hayward and Eckerson (1984) used a rectal temperature of 30°C as a definition of "incipient death." According to Beckman et al. (1966) a rectal temperature of 34.4°C is the time when conscious muscular activity is lost which can result in death by drowning. Thus, for this study, two rectal temperatures (34.4, and 30°C) were used for predicted survival

TABLE III

RESULTS OF COLD WATER IMMERSION EXPERIMENTS

Subject	Core Cooling Rates (°C/h)		Regression Correlation Coefficient		Percentage of Improvement of Vest 2 over Vest 1
	Vest 1	Vest 2	Vest 1	Vest 2	
JA	0.22	0.18	-0.97	-0.98	18%
PP	0.33	0.57	-0.79	-0.98	-42%
MS	0.89	0.93	-0.95	-0.96	-04%
KB	1.08	0.83	-0.99	-0.98	23%
OB	1.68	0.50	-1.00	-1.00	70%
BP	1.86	1.55	-1.00	-0.99	17%
MJ	2.13	1.35	-0.99	-0.98	37%
AR	2.18	1.06	-1.00	-1.00	51%
KT	3.06	2.13	-1.00	-1.00	30%
GR	3.74	2.43	-1.00	-1.00	35%
Mean	1.72	1.15			
Standard Deviation	1.13	.72			
Level of Significance		.012			

time estimates which are summarized in Table IV.

The means and standard deviations for the two rectal temperatures are given for each type of design in Table IV. For a lethal rectal temperature of 34.4°C, the mean estimated predicted survival time was 6.5 hours for subjects wearing the prototype life preserver and 4.4 hours when the same subjects wore the standard personal flotation device. For a lethal rectal temperature of 30°C, the mean estimated predicted survival time was 11.7 hours for subjects wearing the prototype life preserver and 9.8 hours when the same same subjects wore the standard personal flotation device. For both rectal temperatures, the mean estimated predicted survival time was higher for subjects wearing the prototype life preserver than when the same subjects wore the standard personal flotation device.

Heart rate data are given in Table V for selected time intervals. Upon entry into the cold water all of the subjects had an initial large increase in heart rate. Within the first minute of immersion the subjects heart rates were 35 percent and 33 percent above preimmersion levels while wearing Vest 1 and Vest 2 respectively. By five minutes heart rates fell to levels slightly less than preimmersion. Thereafter, heart rates increased gradually for both vests.

During the 5 and 10 minute intervals of cold water immersion the type of design worn did not significantly affect heart rates. However, beginning at 20 minutes of the immersion, the mean heart rate for subjects wearing the prototype life preserver was 80.8 bpm and 86.6 bpm when the

TABLE IV

PREDICTED SURVIVAL TIME ESTIMATES

Subject	Survival Time Estimates given in Hours for Descent to Two Rectal Temperatures			
	34.4°C		30°C	
	Vest 1	Vest 2	Vest 1	Vest 2
JA	14.7	19.0	34.5	43.4
PP	12.0	6.6	25.4	14.3
MS	3.7	3.9	8.7	8.6
KB	3.2	4.1	7.3	9.4
OB	1.8	6.4	4.4	15.3
BP	2.3	2.6	4.7	5.4
MJ	1.7	2.7	3.7	5.9
AR	2.1	3.4	4.1	7.5
KT	1.2	1.8	2.7	3.9
GR	1.0	1.5	2.2	3.3
Mean	4.4	6.5	9.8	11.7
Standard Deviation	4.9	6.9	11.0	11.8

TABLE V

HEART RATE

Subject	Heart Rate (bpm) given at Five Timed Intervals (min) and at Exit											
	5		10		20		30		40		Exit Water	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
JA	91	79	84	84	85	85	85	82	88	78	94	87
PP	82	89	78	84	71	79	72	79	79	86	100	62
MS	62	67	70	77	77	70	88	77	84	82	102	90
KB	90	82	88	76	80	67	86	71	87	74	103	86
OB	78	93	82	86	82	79	79	78	76	79	83	91
BP	83	78	81	70	76	70	81	73	80	75	88	81
MJ	107	106	104	92	104	93	120	92	122	94	120	111
AR	103	94	102	96	107	94	107	97	107	96	102	86
KT	106	108	110	105	107	99	107	101	105	102	106	103
GR	65	74	68	74	77	72	84	74	89	74	89	70
Mean	86.7	87.0	86.7	84.4	86.6	80.8	90.9	82.4	91.7	84.0	98.7	86.7
SD	15.9	13.5	14.3	10.9	13.9	11.4	15.2	10.5	14.8	10.1	10.7	14.2
Level of Significance	.917		.378		.019		.017		.038		.012	

Legend: V1 represents the standard personal flotation device, V2 represents the prototype life preserver.

same subjects wore the standard personal flotation device. At 30 minutes, the mean heart rate for subjects wearing the prototype life preserver was 82.4 bpm and 90.9 bpm when the same subjects wore the standard personal flotation device. At 40 minutes, the mean heart rate for subjects wearing the prototype life preserver was 84.0 bpm and 91.7 bpm when the same subjects wore the standard personal flotation device. During the last four minutes of exposure, the mean heart rate for subjects wearing the prototype life preserver was 86.7 bpm and 98.7 bpm when the same subjects wore the standard personal flotation device. These differences in heart rate were statistically significant at the .05 level for time intervals 20, 30, 40 and the last four minutes of immersion. These differences suggest that the prototype life preserver aided in providing thermal protection and delayed the shivering response to cold water. Less shivering and lower heart rates would conserve energy to be available later to protect against hypothermia for a longer period of time.

A study by Bynum, Goldman and Stewart, (1980) found that the mean increase in metabolic heat production for subjects wearing neoprene insulated suits (15 W/m^2) was lower than when the same subjects were nude (130 W/m^2). This suggests that an important effect of additional insulation is to conserve metabolic energy which is associated with maintaining a given level of rectal temperature (Bynum et al., 1980). This study was done in 20°C water over a 60 minute period.

This conservation of metabolic energy appears to be a possible explanation as to why subject PP did not show a decrease in the rate of cooling when wearing the prototype life preserver over the standard personal flotation device. From visual observation, subject PP appeared to have significantly more total body fat than any of the other subjects. It is therefore, hypothesized that the subject's own tissue insulation plus the insulation provided by the prototype life preserver may have decreased stimulation of deep thermoreceptors. This may have reduced the intensity of a response to a change in temperature. As indicated in Figure 12, the subject's rectal temperature appeared to level off at approximately 60 minutes when wearing the standard personal flotation device and approximately 100 minutes when wearing the prototype life preserver. Thus, a longer exposure time may have showed a decrease in the rate of cooling when the subject was wearing the prototype life preserver over the standard personal flotation device. More work would have to be done to verify this.

Another subject (MS) also did not show a decrease in the rate of cooling when wearing the prototype life preserver over the standard personal flotation device. A possible explanation relates to the amount of urine volume that each subject had during the experiments. When subject MS was wearing the standard personal flotation device, he had a urine volume of 830 cubic centimeters. When he was wearing the prototype life preserver he had a urine volume of 300 cubic centimeters. The subject stated that while

wearing the standard personal flotation device he had a strong urge to urinate. Each time he tryed to relax, the urge to urinate would return which would cause him to tighten up and shiver. However, when the subject was wearing the prototype life preserver he stated that he could relax and abstain from shivering for short periods of time. Thus, it is hypothesized that if the subject had similar urine volumes during each experiment, he may have shown a small decrease in the rate of cooling when wearing the prototype life preserver over the standard personal flotation device. Again, more work would have to be done to verify this. Subject MS was also one of the heavier subjects with a greater body mass.

Based on weight and height alone, it also appears that the heavy subjects (JA, PP, MS and KB) would need a longer exposure time to see significant differences in cooling rate.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This research was conducted to develop and evaluate a thermal protective life preserver for cold water immersion. The objectives of the study were: (1) to develop a prototype life preserver that met the FAA specifications, (2) to test and evaluate the thermal response characteristics of human subjects wearing the prototype life preserver and a currently used standard personal flotation device, and (3) to estimate a predicted survival time for human subjects wearing the prototype life preserver and a currently used standard personal flotation device.

A review of literature focused on physiological responses to cold water immersion and various design concepts previously developed and evaluated for protection against hypothermia. The review of literature was a source of design ideas for the development of the prototype thermal protective life preserver. Information as to the type of materials and closure devices used in cold weather survival gear was also obtained when doing the review of literature.

In the development of the prototype life preserver, specifications required by the FAA were used as guidelines. The researcher determined that the requirements for

self-righting, donning time, universal sizing and weight and storage space limited the amount of thermal protection that could be provided. In order to meet the donning time and weight and storage specifications, a single-chamber air bladder that covered the major heat loss areas of the upper torso was designed. To allow for ease of donning, the air bladder was developed into a jacket style bladder with a front zipper closure. In comparison, the current standard personal flotation device is a dual-chamber air bladder that is U-shaped, encompasses only the neck area and has complicated retention harnesses which prolong donning time.

Since thermal protection is significantly increased when a suit provides a close fit, means of accommodating the need for universal sizing and a close fit were sought. Anthropometric data for males and females were used to specify critical measurements. A material search resulted in the use of one-eight inch closed cell neoprene in the lower back region of the prototype. The 300 percent stretch provided universal sizing and helped achieve a close fit for the designated population.

To test and evaluate the thermal response characteristics of the prototype life preserver and a currently used standard personal flotation device, a laboratory experiment with ten subjects was conducted. Each subject's rectal temperature was measured and recorded every two minutes. A cooling rate for each subject in each design was determined by least-squares regression. A paired t-test was used to

determine significant differences between cooling rate for the two vests.

The mean cooling rate estimates of subjects wearing the prototype life preserver (1.15°C/h) was lower than when the same subjects wore the standard personal flotation device (1.72°C/h). Differences in cooling rate were statistically significant at the .05 level. Regression analysis showed that there was a high degree of correlation between the immersion time and the change in rectal temperature. Eight out of ten subjects while wearing the prototype life preserver showed a decrease in the rate of cooling over the standard personal flotation device.

In order to further evaluate the practical significance of increased thermal protection, the cooling rate data of the present study were used to predict durations to two rectal temperatures (34.4 and 30°C) in 12.8°C water. Hayward's (1975) formula was used with the cooling rate data to estimate predicted survival time. For both rectal temperatures, the mean estimated predicted survival time was higher for subjects wearing the prototype life preserver than when the same subjects wore the standard personal flotation device.

Each subject's heart rate for each vest was recorded continually on a EKG polygraph. Recorded heart rates were counted at the 5, 10, 20, 30, and 40 minute intervals. Recorded heart rates were also counted during the last four minutes of each subject's immersion test when the rectal

temperature was expected to be minimal. A paired t-test was used to determine significant differences between heart rate for the two vests.

During the 5 and 10 minute intervals of cold water immersion, the type of design worn did not significantly affect heart rates. However, beginning at 20 minutes of the immersion, the mean heart rate for subjects wearing the prototype life preserver was 80.8 bpm and 86.6 bpm when the same subjects wore the standard personal flotation device. This difference in heart rate was statistically significant at the .05 level. This difference was pronounced as time progressed. This suggests that the prototype life preserver aided in providing thermal protection and delayed the shivering response to cold water. Less shivering and lower heart rates would conserve energy to be available later to protect against hypothermia for a longer period of time.

Conclusions

The following general conclusions were drawn from the study:

1) Under the conditions of the test, the prototype life preserver provided additional thermal protection for eight out of ten subjects.

2) The prototype life preserver provided 35 pounds of buoyancy as required by the Technical Standard Order C13d.

3) The prototype life preserver was able to self-right the wearer in five seconds as required by the Technical Standard Order C13d.

4) The prototype life preserver appeared to provide universal sizing for individuals from the 5th percentile adult female to the 95th percentile adult male in the United States population.

5) The prototype life preserver provided an average donning time of 17.5 seconds.

6) The prototype life preserver met the airlines' weight and storage requirements.

Recommendations

Based on the results of the study and the review of literature the following recommendations are made:

1) It appears that the prototype life preserver has superior features over the standard personal flotation devices currently being used by commercial aircraft passengers. The features are enhanced thermal protection, improved donning time, and elimination of channeling of water to the face. Thus, further development and cost benefit studies should be pursued.

2) The prototype life preserver should be evaluated for its suitability in air carrier operations, commuter aircraft and general avaition.

3) The prototype life preserver should be evaluated using female subjects.

4) The prototype life preserver should be evaluated at various water temperatures.

5) The prototype life preserver should be evaluated

under the conditions of a field trial.

6) The prototype life preserver should be evaluated using large subjects under longer exposure time conditions.

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APPENDIXES

APPENDIX A

CORRESPONDENCE USED IN THE STUDY

Oklahoma State University

DEPARTMENT OF CLOTHING, TEXTILES & MERCHANDISING

STILLWATER, OKLAHOMA 74078
HOME ECONOMICS WEST 312
(405) 624-5034

I am currently conducting a research on the development and evaluation of a thermal protective life preserver for cold water immersion at Oklahoma State University.

I would appreciate it, if you could send me any catalogues, information, etc. on the availability of equipment and supplies that you may have in regard to the development of this type of life preserver.

Sincerely,

Bernard Rueschhoff
CTM Department

APPENDIX B

CONSENT FORM

CONSENT FORM - HUMAN TEST SUBJECT

I, the undersigned employee do voluntarily give my informed consent for my participation as a test subject for the evaluation of the thermal protective value of prototype life preservers. I understand that the tests will be conducted at the Civil Aeromedical Institute under the direction of Dr. E. Arnold Higgins, Principal Investigator. The proposed human research has been explained to me to my satisfaction, prior to the execution of this Consent Form, and I understand that I may withdraw this consent at any time unless the withdrawal is unwise, dangerous, or impossible. Based on the above considerations, I volunteer and agree to perform these duties as a part of my employment through Data Monitoring Systems and understand that I will be questioned and examined medically prior to being granted clearance to participate in such tests.

My consent to participate as a test subject in the evaluation of the thermal protective value of prototype life preservers shall not be construed as a release of either Data Monitoring Systems or the FAA from any future liability which may arise from or in connection with the above tests or experiments. I understand that the usual insurance coverage for all test-related activities resulting in injuries and illnesses will be State Workers' Compensation coverage carried by Data Monitoring Systems.

APPROVED:

_____ _____

Test Subject Date

_____ _____

Principal Investigator Date

APPENDIX C

SUBJECT INFORMATION SHEET

SUBJECT INFORMATION SHEET

This laboratory studies the thermal protection characteristics of life preservers used aboard aircraft. We will be working with the standard personal flotation device and one prototype thermal protective life preserver in these tests. We want to know the thermal protection value of the new prototype life preserver. We will be comparing the prototype life preserver with the standard personal flotation device. The studies will be conducted in the CAMI survival tank in 55°F water.

Your participation will require you to be here three times. Today, you will be given a physical examination. You will be required to provide a medical history and to give blood and urine samples for analyses.

After passing the physical exam, you will go to the survival tank where you will then be instrumented. Instrumentation will require you to be fitted with adhesive chest electrodes to which wires will be connected for the recording of heart rate and electrocardiogram (EKG). It will also require you to place a rectal temperature sensor device inside the rectum, approximately 10 cm (4") for the measurement of internal body temperature. After instrumentation is completed, you will put on the standard personal flotation device and then enter the 55°F water for a 15 minute period.

When you return for the next test session, you will first see the physician briefly to assure that your physical condition has not changed since your physical exam. You will also report fasted (no food or drink expect water) since midnight of the preceding day. If no changes in your physical condition are detected, you will then go to the survival tank where you will be instrumented as during the trial test. There will be two other subjects participating at the same time. You will be tethered while in the pool and have your own individual observer. The EKG will be used for monitoring the heart rate and any electrocardiographic abnormality. The measurement of the rectal temperature will be used to determine the thermal protection characteristics of each life preserver.

You will be removed from the survival tank if your rectal temperature reaches 35°C or on your request. At this time you will be escorted to an adjacent room where you remove the vests, towel dry, take off the wet shorts and put on sweat suits. During the changing of the garments, the rectal temperature sensor device must remain inserted. After you have changed you will then sit in a room until your internal body temperature reaches 36.5°C. During this time you will be provided Gatorade to drink. After reaching 36.5°C you will remove the temperature sensor device. You will then take a shower and get dressed.

After the test, you will be held for observation for 2 hours. During this time you will be offered additional fluids to drink. Cold water immersion increases diuresis which will cause some dehydration.

During the test, you will be photographed on video tape above and below the water.

RISKS. During the exposure to the cold water, there could be discomfort and intense shivering. Due to the water immersion and to the cold, there will be significant shifts in the body fluid com- partments. This could lead to changes in the heart rate and rhythms. These could range all the way from insignificant changes (which is usually the case) to changes serious enough to be life threatening and requiring immediate medical intervention and treatment of the condition. The probability of a serious response is highly improbable. The capability for medical intervention will be immediately available at poolside. During rewarming, after leaving the cold water, the body fluids are again redistributed and the same hazards of changes in cardiac rhythms are again present. Also, during rewarming there could be discomfort produced, especially in the extremities, due to the change in blood flow and temperature.

During the exposure the body will become dehydrated. As stated above, drinks will only be provided after the water immersion to replace body fluids and some of the electrolytes.

While in the water wearing electrodes and probes which are connected to recording equipment, there is a potential hazard of electrical shock. Proper grounding and isolation techniques will be used to control this hazard and prevent any injury to you.

Due to the water and wet feet there is an increased possi- bility of slipping and possibly falling. We ask that you be aware of this and take extra caution.

The pool that you will be tested in is 14 feet deep, but the vest, tethering and personal observers are designed to prevent any "drowning" risk.

APPENDIX D

MEDICAL HISTORY

STANDARD FORM 93
REV. OCTOBER 1974
GSA FPMR 101–11.8

APPROVED
OFFICE OF MANAGEMENT AND BUDGET No. 29–R0191

REPORT OF MEDICAL HISTORY

(THIS INFORMATION IS FOR OFFICIAL AND MEDICALLY-CONFIDENTIAL USE ONLY AND WILL NOT BE RELEASED TO UNAUTHORIZED PERSONS)

1. LAST NAME—FIRST NAME—MIDDLE NAME	2. SOCIAL SECURITY OR SERVICE NO.
3. HOME ADDRESS *(No. street or RFD, city or town, State, and ZIP CODE)*	4. REGION (Title, grade, component)
5. PURPOSE OF EXAMINATION	6. DATE OF EXAMINATION / 7. EXAMINING FACILITY OR EXAMINER, AND ADDRESS (Include ZIP Code)

8. STATEMENT OF EXAMINEE'S PRESENT HEALTH AND MEDICATIONS CURRENTLY USED *(Follow by description of past history, if complaint exists)*

9. HAVE YOU EVER *(Please check each item)*			10. DO YOU *(Please check each item)*		
YES	NO	*(Check each item)*	YES	NO	*(Check each item)*
		Lived with anyone who had tuberculosis			Wear glasses or contact lenses
		Coughed up blood			Have vision in both eyes
		Bled excessively after injury or tooth extraction			Wear a hearing aid
		Attempted suicide			Stutter or stammer habitually
		Been a sleepwalker			Wear a brace or back support

11. HAVE YOU EVER HAD OR HAVE YOU NOW *(Please check at left of each item)*

YES	NO	DON'T KNOW	*(Check each item)*	YES	NO	DON'T KNOW	*(Check each item)*	YES	NO	DON'T KNOW	*(Check each item)*
			Scarlet fever, erysipelas				Cramps in your legs				"Trick" or locked knee
			Rheumatic fever				Frequent indigestion				Foot trouble
			Swollen or painful joints				Stomach, liver, or intestinal trouble				Neuritis
			Frequent or severe headache				Gall bladder trouble or gallstones				Paralysis (include infantile)
			Dizziness or fainting spells				Jaundice or hepatitis				Epilepsy or fits
			Eye trouble				Adverse reaction to serum, drug,				Car, train, sea or air sickness
			Ear, nose, or throat trouble				or medicine				Frequent trouble sleeping
			Hearing loss				Broken bones				Depression or excessive worry
			Chronic or frequent colds				Tumor, growth, cyst, cancer				Loss of memory or amnesia
			Severe tooth or gum trouble				Rupture/hernia				Nervous trouble of any sort
			Sinusitis				Piles or rectal disease				Periods of unconsciousness
			Hay Fever				Frequent or painful urination				
			Head injury				Bed wetting since age 12				
			Skin diseases				Kidney stone or blood in urine				
			Thyroid trouble				Sugar or albumin in urine				
			Tuberculosis				VD—Syphilis, gonorrhea, etc.				
			Asthma				Recent gain or loss of weight				
			Shortness of breath				Arthritis, Rheumatism, or Bursitis				
			Pain or pressure in chest				Bone, joint or other deformity				
			Chronic cough				Lameness				
			Palpitation or pounding heart				Loss of finger or toe	12. FEMALES ONLY: HAVE YOU EVER			
			Heart trouble				Painful or "trick" shoulder or elbow				Been treated for a female disorder
			High or low blood pressure				Recurrent back pain				Had a change in menstrual pattern

13. WHAT IS YOUR USUAL OCCUPATION?	14. ARE YOU *(Check one)* ☐ Right handed ☐ Left handed

93–102

YES	NO	CHECK EACH ITEM YES OR NO. EVERY ITEM CHECKED YES MUST BE FULLY EXPLAINED IN BLANK SPACE ON RIGHT	
		15. Have you been refused employment or been unable to hold a job or stay in school because of: A. Sensitivity to chemicals, dust, sunlight, etc.	
		B. Inability to perform certain motions.	
		C. Inability to assume certain positions.	
		D. Other medical reasons *(If yes, give reasons.)*	
		16. Have you ever been treated for a mental condition? *(If yes, specify when, where, and give details).*	
		17. Have you ever been denied life insurance? *(If yes, state reason and give details.)*	
		18. Have you had, or have you been advised to have, any operations? *(If yes, describe and give age at which occurred.)*	
		19. Have you ever been a patient in any type of hospitals? *(If yes, specify when, where, why, and name of doctor and complete address of hospital.)*	
		20. Have you ever had any illness or injury other than those already noted? *(If yes, specify when, where, and give details.)*	
		21. Have you consulted or been treated by clinics, physicians, healers, or other practitioners within the past 5 years for other than minor illnesses? *(If yes, give complete address of doctor, hospital, clinic, and details.)*	
		22. Have you ever been rejected for military service because of physical, mental, or other reasons? *(If yes, give date and reason for rejection.)*	
		23. Have you ever been discharged from military service because of physical, mental, or other reasons? *(If yes, give date, reason, and type of discharge: whether honorable, other than honorable, for unfitness or unsuitability.)*	
		24. Have you ever received, is there pending, or have you applied for pension or compensation for existing disability? *(If yes, specify what kind, granted by whom, and what amount, when, why.)*	

I certify that I have reviewed the foregoing information supplied by me and that it is true and complete to the best of my knowledge.
I authorize any of the doctors, hospitals, or clinics mentioned above to furnish the Government a complete transcript of my medical record for purposes of processing my application for this employment or service.

TYPED OR PRINTED NAME OF EXAMINEE	SIGNATURE

NOTE: HAND TO THE DOCTOR OR NURSE, OR IF MAILED MARK ENVELOPE "TO BE OPENED BY MEDICAL OFFICER ONLY."

25. Physician's summary and elaboration of all pertinent data *(Physician shall comment on all positive answers in items 9 through 24. Physician may develop by interview any additional medical history he deems important, and record any significant findings here.)*

TYPED OR PRINTED NAME OF PHYSICIAN OR EXAMINER	DATE	SIGNATURE	NUMBER OF ATTACHED SHEETS

REVERSE OF STANDARD FORM 93

☆U.S.GPO:1982-0-381-528/8042

APPENDIX E

MEDICAL EXAMINATION

Standard Form 88
(Rev. June 1956)
Bureau of the Budget
Circular A-32 (Rev)

REPORT OF MEDICAL EXAMINATION

88-112

1. LAST NAME—FIRST NAME—MIDDLE NAME		2. GRADE AND COMPONENT OR POSITION	3. IDENTIFICATION NO.
4. HOME ADDRESS (*Number, street or R.F.D., city or town, State and ZIP code*)		5. PURPOSE OF EXAMINATION	6. DATE OF EXAMINATION
7. SEX	8. RACE	9. TOTAL YEARS GOVERNMENT SERVICE: MILITARY / CIVILIAN	10. AGENCY / 11. ORGANIZATION UNIT
12. DATE OF BIRTH	13. PLACE OF BIRTH	14. NAME, RELATIONSHIP, AND ADDRESS OF NEXT OF KIN	
15. EXAMINING FACILITY OR EXAMINER, AND ADDRESS		16. OTHER INFORMATION	
17. RATING OR SPECIALTY		TIME IN THIS CAPACITY (*Total*)	LAST SIX MONTHS

CLINICAL EVALUATION

NORMAL	(Check each item in appropriate column; enter "NE" if not evaluated.)	ABNORMAL
	18. HEAD, FACE, NECK AND SCALP	
	19. NOSE	
	20. SINUSES	
	21. MOUTH AND THROAT	
	22. EARS—GENERAL (*Ext. & ext. canals*) (*Auditory acuity under items 70 and 71*)	
	23. DRUMS (*Perforation*)	
	24. EYES—GENERAL (*Visual acuity and refraction under items 59, 60 and 67*)	
	25. OPHTHALMOSCOPIC	
	26. PUPILS (*Equality and reaction*)	
	27. OCULAR MOTILITY (*Associated parallel movements, nystagmus*)	
	28 LUNGS AND CHEST (*Include breasts*)	
	29. HEART (*Thrust, size, rhythm, sounds*)	
	30. VASCULAR SYSTEM (*Varicosities, etc.*)	
	31. ABDOMEN AND VISCERA (*Include hernia*)	
	32. ANUS AND RECTUM (*Hemorrhoids, fistulae*) (*Prostate, if indicated*)	
	33. ENDOCRINE SYSTEM	
	34 G-U SYSTEM	
	35. UPPER EXTREMITIES (*Strength, range of motion*)	
	36. FEET	
	37. LOWER EXTREMITIES (*Except feet*) (*Strength, range of motion*)	
	38. SPINE, OTHER MUSCULOSKELETAL	
	39. IDENTIFYING BODY MARKS, SCARS, TATTOOS	
	40. SKIN, LYMPHATICS	
	41. NEUROLOGIC (*Romberg tests under item 78*)	
	42. PSYCHIATRIC (*Specify any personality deviation*)	
	43. PELVIC (*Females only*) (*Check how done*) ☐ VAGINAL ☐ RECTAL	

NOTES. (*Describe every abnormality in detail. Enter pertinent item number before each comment. Continue in item 73 and use additional sheets if necessary.*)

(*Continue in item 73*)

44. DENTAL (*Place appropriate symbols above or below number of upper and lower teeth, respectively.*)

O—*Restorable teeth* /—*Nonrestorable teeth* X—*Missing teeth* XXX—*Replaced by dentures* (*6 X 8*)—*Fixed bridge, brackets to include abutments*

RIGHT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	LEFT
	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	

REMARKS AND ADDITIONAL DENTAL DEFECTS AND DISEASES

LABORATORY FINDINGS

45. URINALYSIS: A. SPECIFIC GRAVITY			46. CHEST X-RAY (*Place, date, film number and result*)
B. ALBUMIN	D. MICROSCOPIC		
C. SUGAR			
47. SEROLOGY (*Specify test used and result*)	48. EKG	49. BLOOD TYPE AND RH FACTOR	50. OTHER TESTS Hct, Hb, WEC Diff if indicated

MEASUREMENTS AND OTHER FINDINGS

51. HEIGHT	52. WEIGHT	53. COLOR HAIR	54. COLOR EYES	55. BUILD: (Check one)	SLENDER	MEDIUM	HEAVY	OBESE	56. TEMPERATURE

57. BLOOD PRESSURE (Arm at heart level)						58. PULSE (Arm at heart level)				
A. SITTING	SYS. / DIAS.	B. RECUMBENT	SYS. / DIAS.	C. STANDING (5 min.)	SYS. / DIAS.	A. SITTING	B. AFTER EXERCISE	C. 2 MIN. AFTER	D. RECUMBENT	E. AFTER STANDING 3 MIN.

59. DISTANT VISION		60. REFRACTION			61. NEAR VISION	
RIGHT 20/	CORR. TO 20/	BY	S.	CX	CORR. TO	BY
LEFT 20/	CORR. TO 20/	BY	S.	CX	CORR. TO	BY

62. HETEROPHORIA (*Specify distance*)

ES°	EX°	R. H.	L. H.	PRISM DIV.	PRISM CONV. CT	PC	PD

63. ACCOMMODATION		64. COLOR VISION (*Test used and result*)	65. DEPTH PERCEPTION (*Test used and score*)	UNCORRECTED
RIGHT	LEFT			CORRECTED
66. FIELD OF VISION		67. NIGHT VISION (*Test used and score*)	68. RED LENS TEST	69. INTRAOCULAR TENSION

70. HEARING			71. AUDIOMETER								72. PSYCHOLOGICAL AND PSYCHOMOTOR (*Tests used and score*)
RIGHT WV	/15 SV	/15		250 *256*	500 *512*	1000 *1024*	2000 *2048*	3000 *2890*	4000 *4096*	6000 *6144*	8192 *8190*	
LEFT WV	/15 SV	/15	RIGHT									
			LEFT									

73. NOTES (*Continued*) AND SIGNIFICANT OR INTERVAL HISTORY

(*Use additional sheets if necessary*)

74. SUMMARY OF DEFECTS AND DIAGNOSES (*List diagnoses with item numbers*)

75. RECOMMENDATIONS—FURTHER SPECIALIST EXAMINATIONS INDICATED (*Specify*)

76. A. PHYSICAL PROFILE

P	U	L	H	E	S

77. EXAMINEE (*Check*)

A. ☐ IS QUALIFIED FOR
B. ☐ IS NOT QUALIFIED FOR

B. PHYSICAL CATEGORY

78. IF NOT QUALIFIED, LIST DISQUALIFYING DEFECTS BY ITEM NUMBER

A	B	C	E

79. TYPED OR PRINTED NAME OF PHYSICIAN	SIGNATURE
80. TYPED OR PRINTED NAME OF PHYSICIAN	SIGNATURE
81. TYPED OR PRINTED NAME OF DENTIST OR PHYSICIAN (*Indicate which*)	SIGNATURE
82. TYPED OR PRINTED NAME OF REVIEWING OFFICER OR APPROVING AUTHORITY	SIGNATURE / NUMBER OF ATTACHED SHEETS

U.S. GOVERNMENT PRINTING OFFICE : 1967—O-280-727

APPENDIX F

DATA RECORDING SHEET

Position # _____ Date _____
Subject # _____ Vest # _____
Name _____

Time in pool _____
Time out of pool _____
Time ~~warmed to 97.5°~~ to shower _____

Time	Tr	HR	Time	Tr	HR	Time	Tr	HR
0			50			94		
5			52			96		
10			54			98		
12			56			100		
14			58			102		
16			60			104		
18			62			106		
20			64			108		
22			66			110		
24			68			112		
26			70			114		
28			72			116		
30			74			118		
32			76			120		
34			78					
36			80					
38			82					
40			84					
42			86					
44			88					
46			90					
48			92					

APPENDIX G

SAFETY INSPECTION FORMS

Baptist Medical Center
DC Defibrillator Inspection Form

ACTION	Not Needed	Needed	Taken
Control No.			
Date of Inspection: 1 April 1985			
Next Inspection Due:			

LOCATION FAA CAMI SERIAL NO. 0015023

MODEL LIFEpak 5 MANUFACTURER Physio Control

VISUAL INSPECTION	OK	ACTION NEEDED	ACTION TAKEN (Date & Initials)
1. ATTACHMENT PLUG	✓		
2. LINE CORD & STRAIN RELIEFS	✓		
3. PADDLES, CABLES, & CONNECTORS	N/A		
4. FUSE	N/A		
5. CONDITION OF CONTROLS, INDICATORS & METER	✓		
6. GENERAL CONDITION OF INSTRUMENT	✓		
7. ELECTRODE PASTE OR SALINE PADS	N/A		
8. POSITION OF CONTROLS	✓		

OPERATION

9. LEAKAGE CURRENT TO CHASSIS (Circle unacceptable values).

N/A Applicable - The unit is battery operated

	OFF	ON
Properly Grounded	uA	uA
Ungrounded, Correct Polarity		
Ungrounded, Reversed Polarity		

10. LEAKAGE CURRENT TO PADDLES (Circle unacceptable values):

	OFF	ON	CURRENT BETWEEN PADDLES OFF	CURRENT BETWEEN PADDLES ON
Properly Grounded	uA	uA	uA	uA
Ungrounded, Correct Polarity				
Ungrounded, Reversed Polarity				

11. CHARGING TIME TO MAXIMUM ENERGY SETTING:

12 Sec. to 370 W-sec. Previous Value _____ Sec.

Continued on Reverse Side

DC Defibrillator Inspection Form, Side 2

	OK	ACTION NEEDED	ACTION TAKEN (Date & Initials)
12. INTERNAL DISCHARGE OF STORED ENERGY	NA		
13. OUTPUT ENERGY (watt-seconds)			

CONTROL SETTING	INDICATED ENERGY	DELIVERED ENERGY	PREVIOUS VALUE	CHANGE			
100J		110J					
200J		215J					
300J		320J					
360J		370J					

after 1 min unit has to be recharged

14. ENERGY DELIVERED AFTER 1 MINUTE, MAXIMUM SETTING. ____ W-Sec.	NA		
" " " 0.5 " " " 320 W-Sec			
15. OUTPUT OF TENTH REPEATED DISCHARGE, MAX. SETTING: ____ W-Sec.	NC		
16. SYNCHRONIZER OPERATION	NC		
17. OTHER FEATURES (Specify) CRT - ECG Presentation	✓		
EEG Recorder	✓		

COMMENTS & DESCRIPTION OF DEFICIENCIES (Refer to item numbers)

INSPECTED BY Sally Behrens

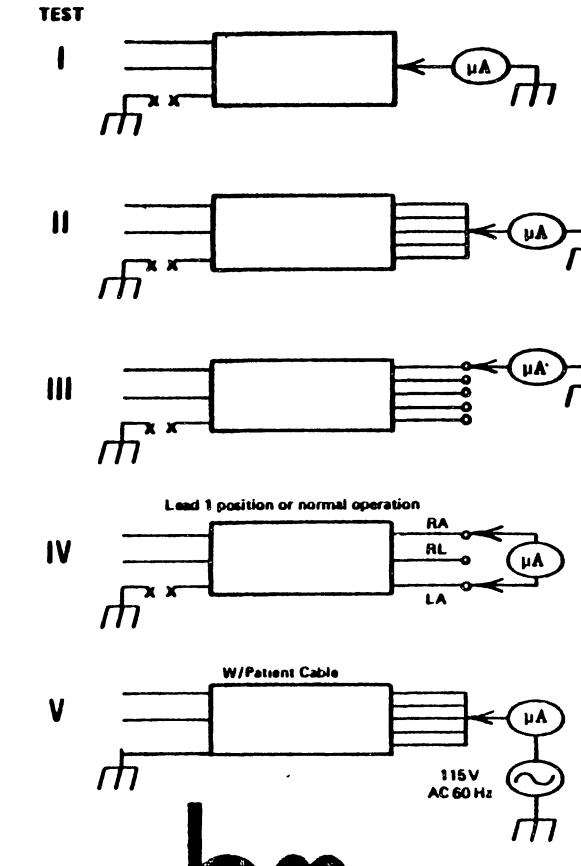
EKG INSPECTION | FAA CAMI | 1 Apr 85

Baptist Medical Center | MODEL EK/SA | SERIAL NUMBER 95818 | PERSON PERFORMING TESTS J. HAYNES

INSTRUMENT MANUFACTURER BURDICK

Gnd 0.08

TEST		GROUNDED		GROUND LIFTED		
		NORMAL POLARITY		NORMAL POLARITY		REVERSE POLARITY
		On	Off	On	Off	On	Off
I	CASE	0.2	0.2 µA	0.2	0.2 µA	0.2	0.2 µA
II	ALL	0.5	0.5 µA	0.5	0.5 µA	0.5	0.5 µA
III	RA	0.5	0.5 µA	0.5	0.5 µA	0.5	0.5 µA
	LA	0.5	0.5 µA	0.5	0.5 µA	0.5	0.5 µA
	RL	0.5	0.5 µA	0.5	0.5 µA	0.5	0.5 µA
	LL		µA		µA		µA
	C		µA		µA		µA
IV	RA-RL	0.5	0.5 µA	0.5	0.5 µA	0.5	0.5 µA
	LA-RL	0.5	0.5 µA	0.5	0.5 µA	0.5	0.5 µA
	RA-LA	0.5	0.5 µA	0.5	0.5 µA	0.5	0.5 µA



Press to apply 115 V

Note: Before recording Test V, subtract meter factor

(-mf) 38 µA

Red lines indicate reading not to exceed 10 µA for Class 1 requirements in accordance with California Hospital Association preliminary Electrical Safety Code.

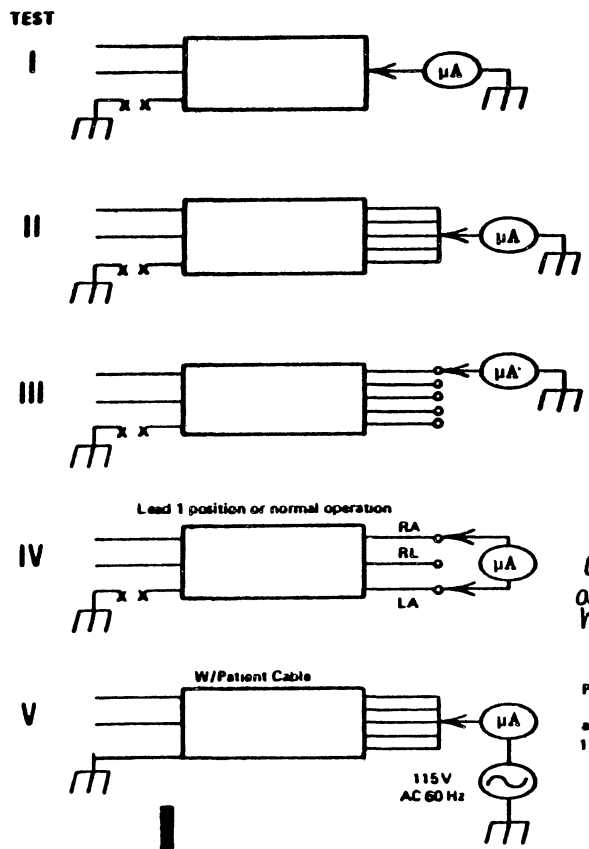
CAUTION: ISOLATE ALL PATIENTS WITH ANY TYPE INDWELLING CATHETERS BY DISCONNECTING ALL EQUIPMENT WITHIN POSSIBLE CONTACT OF THEM BEFORE MAKING TESTS.

BMCBM-6
1 Oct 1974

EKG INSPECTION | FAA CAMI | 1 Apr 85

Baptist Medical Center | MODEL EK/5A | SERIAL NUMBER 77058 | PERSON PERFORMING TESTS J.HAYNES

INSTRUMENT MANUFACTURER BURDICK



	GROUNDED		GROUND LIFTED		
	NORMAL POLARITY		NORMAL POLARITY		REVERSE POLARITY
	On	Off	On	Off	On / Off
	Gnd 0.08Ω				
CASE	0.3	0.3 μA	0.3	0.3 μA	0.3 / 0.3 μA
ALL	0.5	0.5 μA	0.5	0.5 μA	0.5 / 0.5 μA
RA	0.5	0.5 μA	0.5	0.5 μA	0.5 / 0.5 μA
LA	0.5	0.5 μA	0.5	0.5 μA	0.5 / 0.5 μA
RL	0.5	0.5 μA	0.5	0.5 μA	0.5 / 0.5 μA
LL		μA		μA	μA
C		μA		μA	μA
RA-RL		μA		μA	μA
LA-RL		μA		μA	μA
RA-LA		μA		μA	μA

0.5 all Modes

Press to apply 115 V

Note: Before recording Test V, subtract meter factor

(-mf) 33.5 μA

Red lines indicate reading not to exceed 10 μA for Class 1 requirements in accordance with California Hospital Association preliminary Electrical Safety Code.

CAUTION: ISOLATE ALL PATIENTS WITH ANY TYPE INDWELLING CATHETERS BY DISCONNECTING ALL EQUIPMENT WITHIN POSSIBLE CONTACT OF THEM BEFORE MAKING TESTS.

BMCBM-6
1 Oct 1974

86

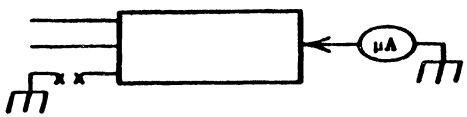
EKG INSPECTION | FAA CAMI | 1 Apr 85

Baptist Medical Center | MODEL EK/5A | SERIAL NUMBER 61640 | PERSON PERFORMING TESTS J HAYNES

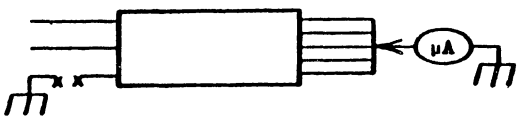
INSTRUMENT MANUFACTURER BURDICK

TEST

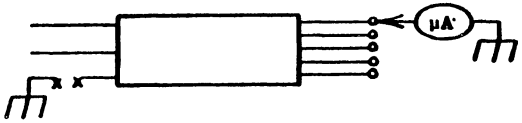
I



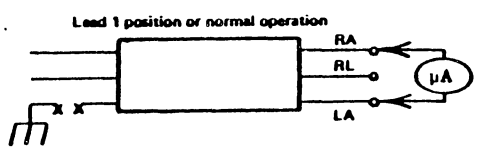
II



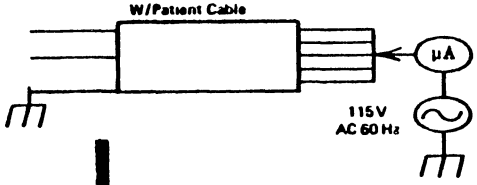
III



IV



V



Press to apply 115 V

	GROUNDED		GROUND LIFTED			
	NORMAL POLARITY		NORMAL POLARITY		REVERSE POLARITY	
	On	Off	On	Off	On	Off
Gnd 0.08						
CASE	0.3	0.3 μA	0.3	0.3 μA	0.3	0.3 μA
ALL	0.5	0.5 μA	0.5	0.5 μA	0.5	0.5 μA
RA	0.5	0.5 μA	0.5	0.5 μA	0.5	0.5 μA
LA	0.5	0.5 μA	0.5	0.5 μA	0.5	0.5 μA
RL	0.5	0.5 μA	0.5	0.5 μA	0.5	0.5 μA
LL		μA		μA		μA
C		μA		μA		μA
RA-RL	0.5	0.5 μA	0.5	0.5 μA	0.5	0 μA
LA-RL	0.5	0.5 μA	0.5	0.5 μA	0.5	0.5 μA
RA-LA	0.5	0.5 μA	0.5	0.5 μA	0.5	0.5 μA

Note: Before recording Test V, subtract meter factor.

(-mf) 39.0 μA

Red lines indicate reading not to exceed 10 μA for Class 1 requirements in accordance with California Hospital Association preliminary Electrical Safety Code.

CAUTION: ISOLATE ALL PATIENTS WITH ANY TYPE INDWELLING CATHETERS BY DISCONNECTING ALL EQUIPMENT WITHIN POSSIBLE CONTACT OF THEM BEFORE MAKING TESTS.

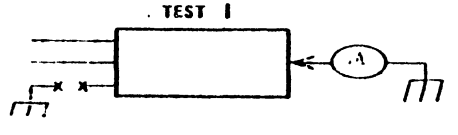
BMCBM-6
1 Oct 1974

LEAKAGE MEASUREMENTS, GENERAL	FAA CAM1	1 Apr 85
Baptist Medical Center	GROUP OR CODE NUMBER	PERSON PERFORMING TESTS JHAYNES

IDENTIFICATION OR SERIAL NUMBER	DESCRIPTION OF INSTRUMENT OR EQUIPMENT Include Model Number	GROUNDED	GROUND LIFTED*	
		NORMAL POLARITY	NORMAL POLARITY	REVERSED POLARITY
M712X0	GRASS MODEL 7	Gnd OFF/ON 0.03/0.5 µA	OFF/ON 0.5/0.5 µA	OFF/ON 0.5/0.5 µA
669	Burdick CSS-61 CardioTach	0.04/0.5/0.5 µA	0.5/0.5 µA	0.5/0.5 µA
—	System all together	0.04/0.4/0.4 µA	0.4/0.5 µA	0.5/0.5 µA
		µA	µA	µA
		µA	µA	µA
		µA	µA	µA
		µA	µA	µA
		µA	µA	µA
		µA	µA	µA
		µA	µA	µA
		µA	µA	µA
		µA	µA	µA
		µA	µA	µA

CAUTION: ISOLATE ALL PATIENTS WITH ANY TYPE INDWELLING CATHETERS BY DISCONNECTING ALL EQUIPMENT WITHIN POSSIBLE CONTACT OF THEM BEFORE MAKING TESTS.

Red lines indicate reading not to exceed 10 µA for Class 1 requirements in accordance with California Hospital Association preliminary Electrical Safety Code.



BMCRM-7
1 Oct 1974

APPENDIX H

BRIEF EXAMINATION

Date _____/_____/_____

Subject # _____ Condition _____

Initials _____

EXPLAIN YES ANSWER BELOW

1.	Have you had a physical or medical problem or illness this past week?	1. yes no
2.	Have you had an upper respiratory infection or congestion this past week?	2. yes no
3.	Have you taken any medication in the past 3 days?	3. yes no
4.	When did you drink an alcoholic beverage last?	4. _____
5.	Are you presently experiencing any:	5.
	a. Fatigue	a. yes no
	b. Drowsiness	b. yes no
	c. Muscle weakness or soreness	c. yes no
	d. Stomach upset	d. yes no
	e. Constipation	e. yes no
	f. Headache	f. yes no
6.	How long did you sleep last night?	6. _____
7.	How well did you sleep last night?	7. _____
8.	How many cups of coffee have you had today?	8. _____
9.	When did you eat last?	9. _____
	List foods:	

APPENDIX I

GRAPHS SHOWING RECTAL TEMPERATURE VS. TIME

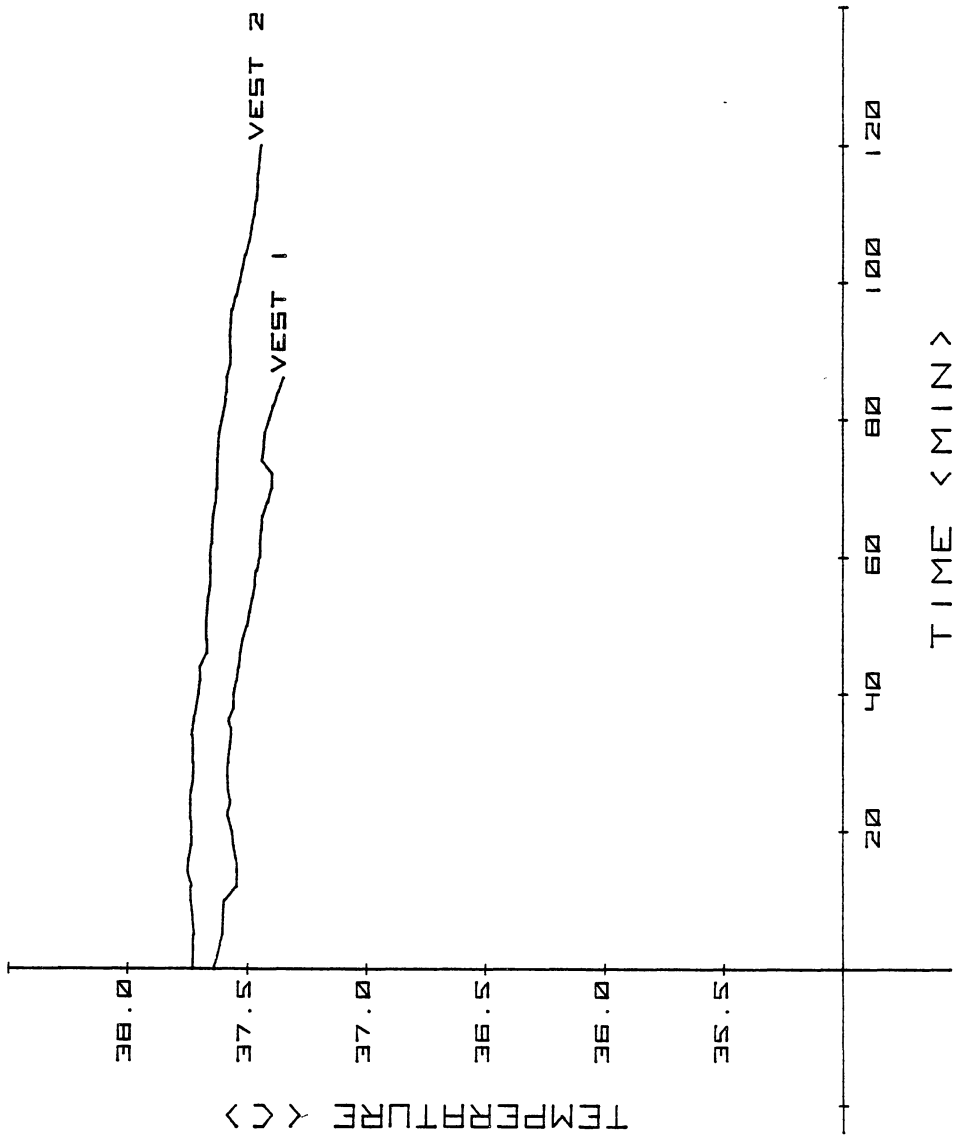


Figure 21. Rectal Temperature VS. Time During Immersion for Subject JA

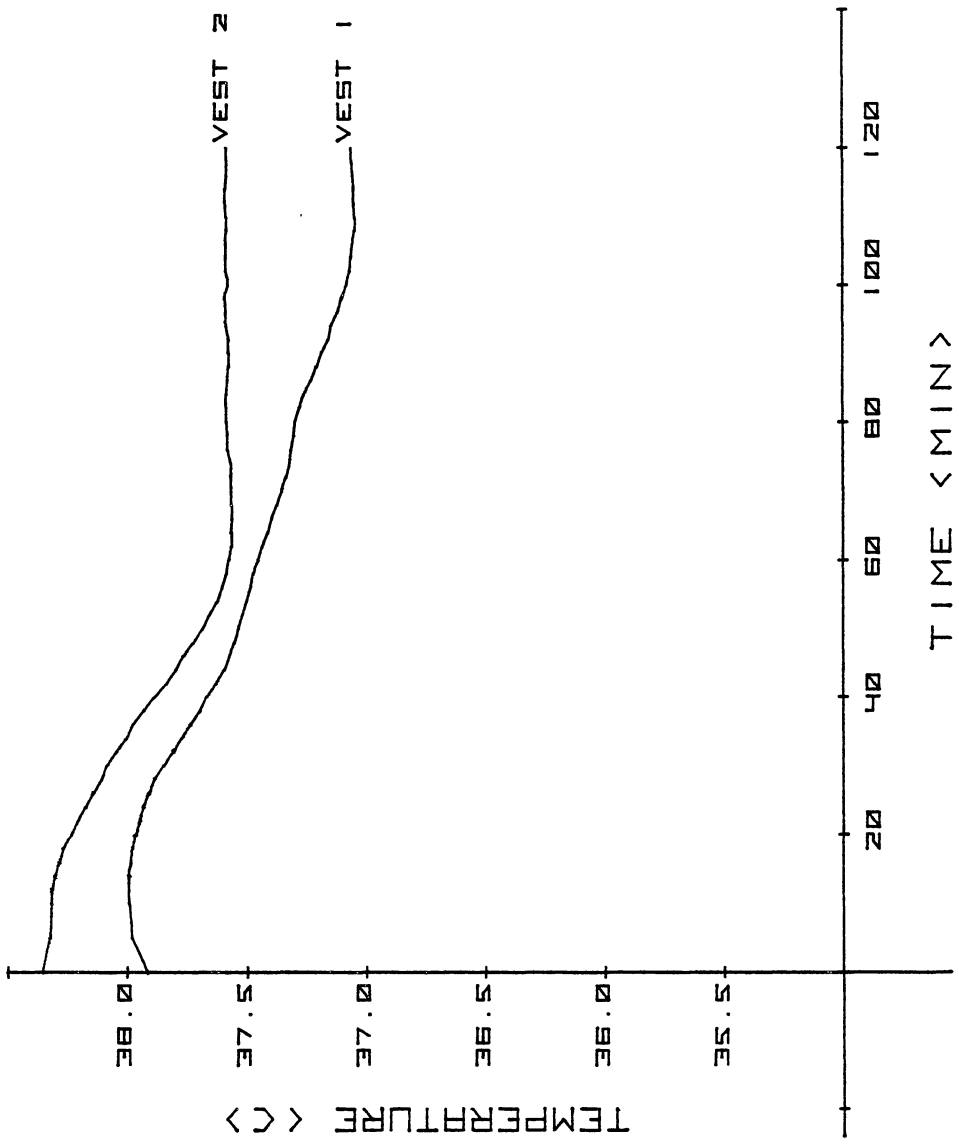


Figure 22. Rectal Temperature VS. Time During Immersion for Subject PP

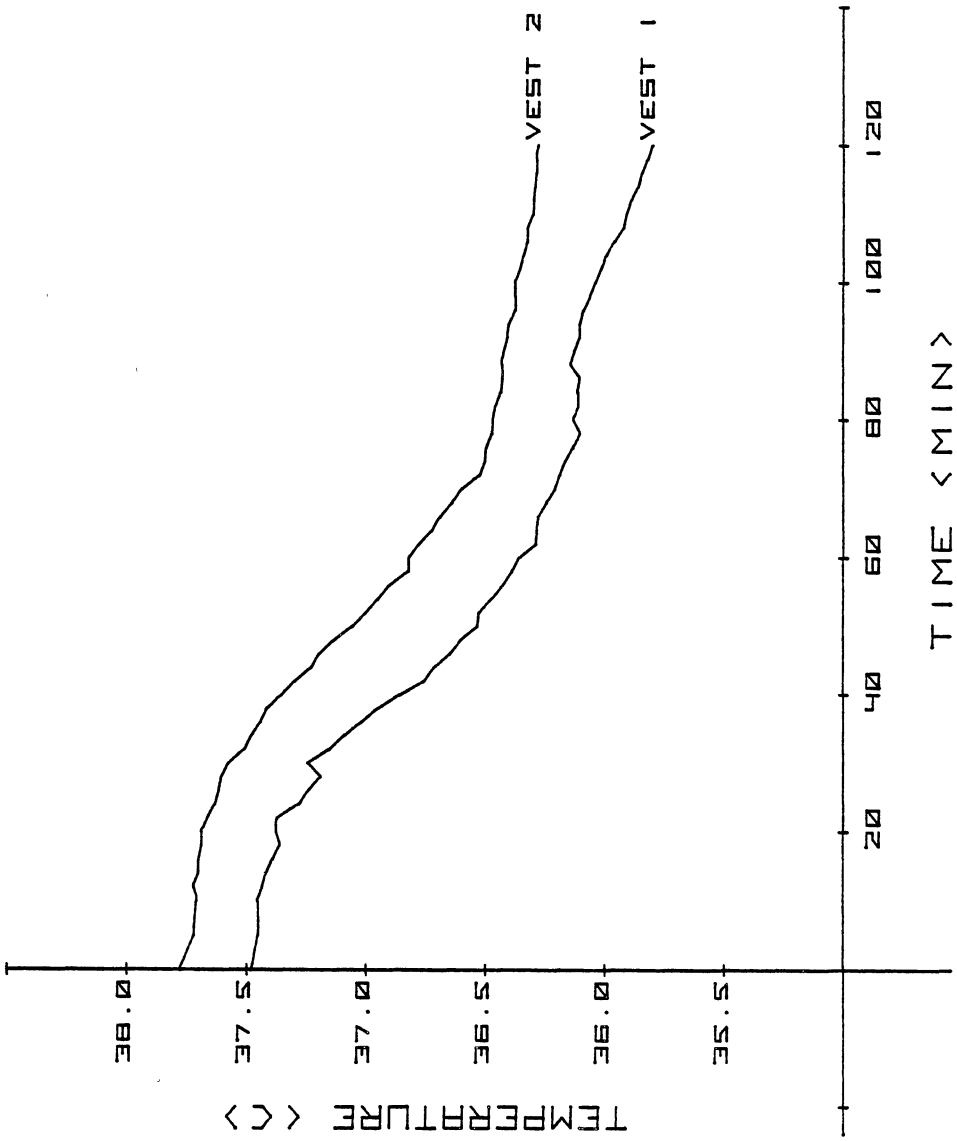


Figure 23. Rectal Temperature VS. Time During Immersion for Subject MS

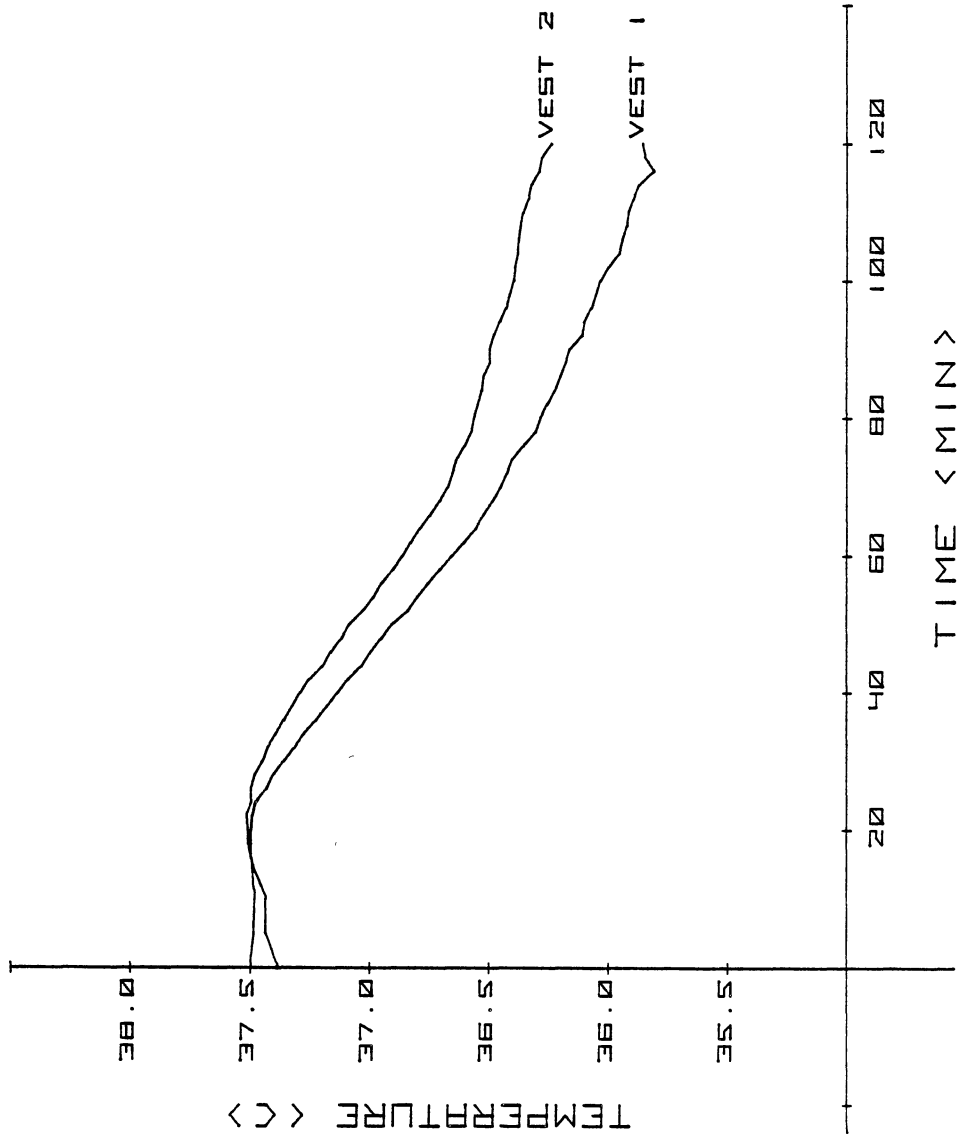


Figure 24. Rectal Temperature VS. Time During Immersion for Subject KB

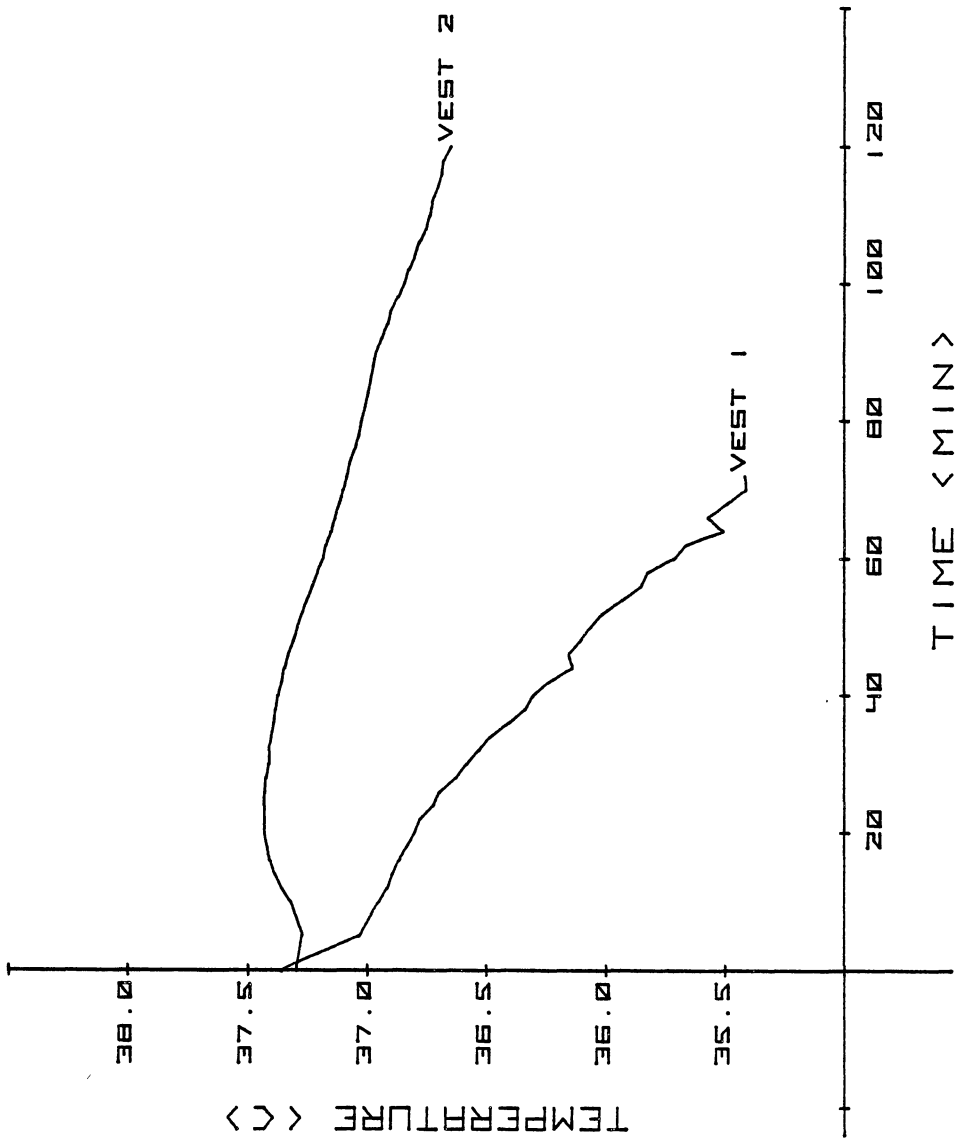


Figure 25. Rectal Temperature VS. Time During Immersion for Subject 08

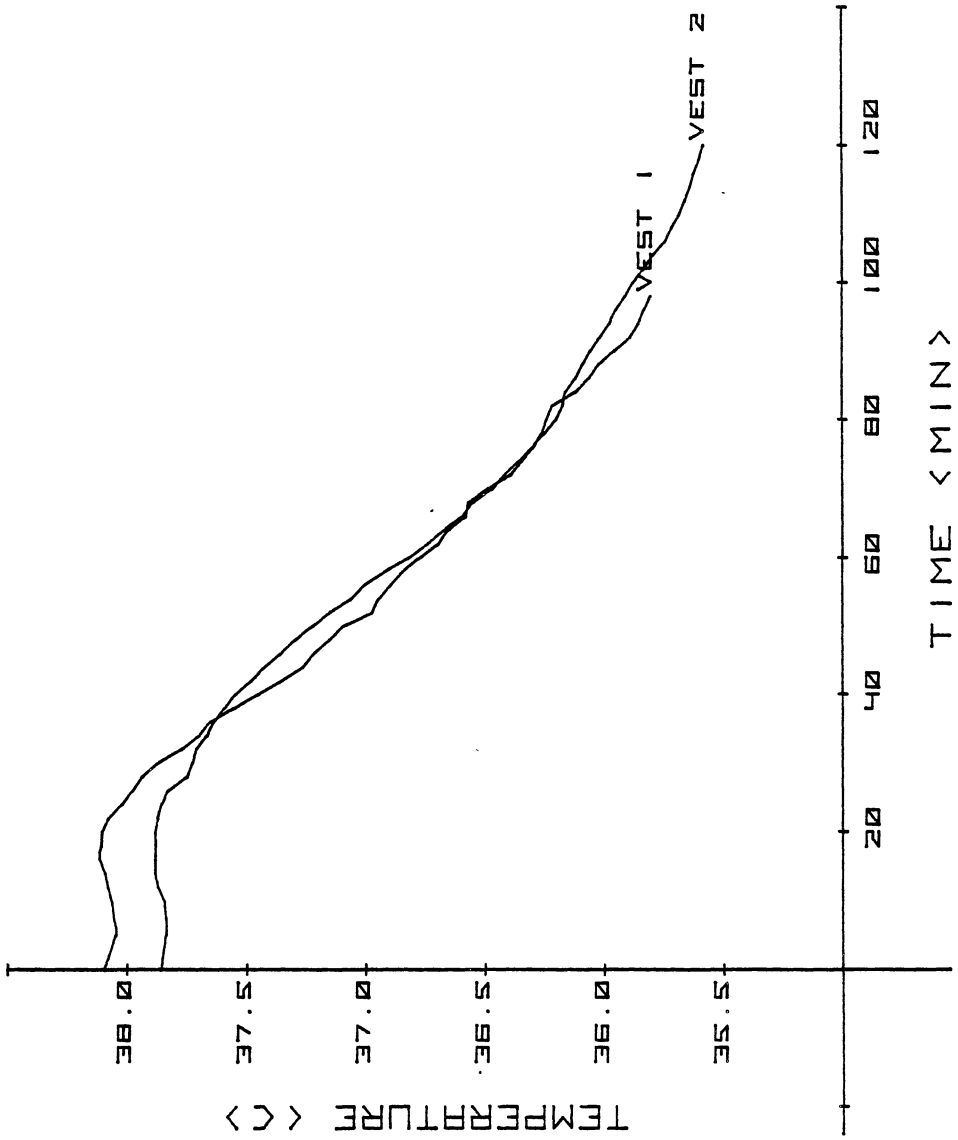


Figure 26. Rectal Temperature VS. Time During Immersion for Subject BP

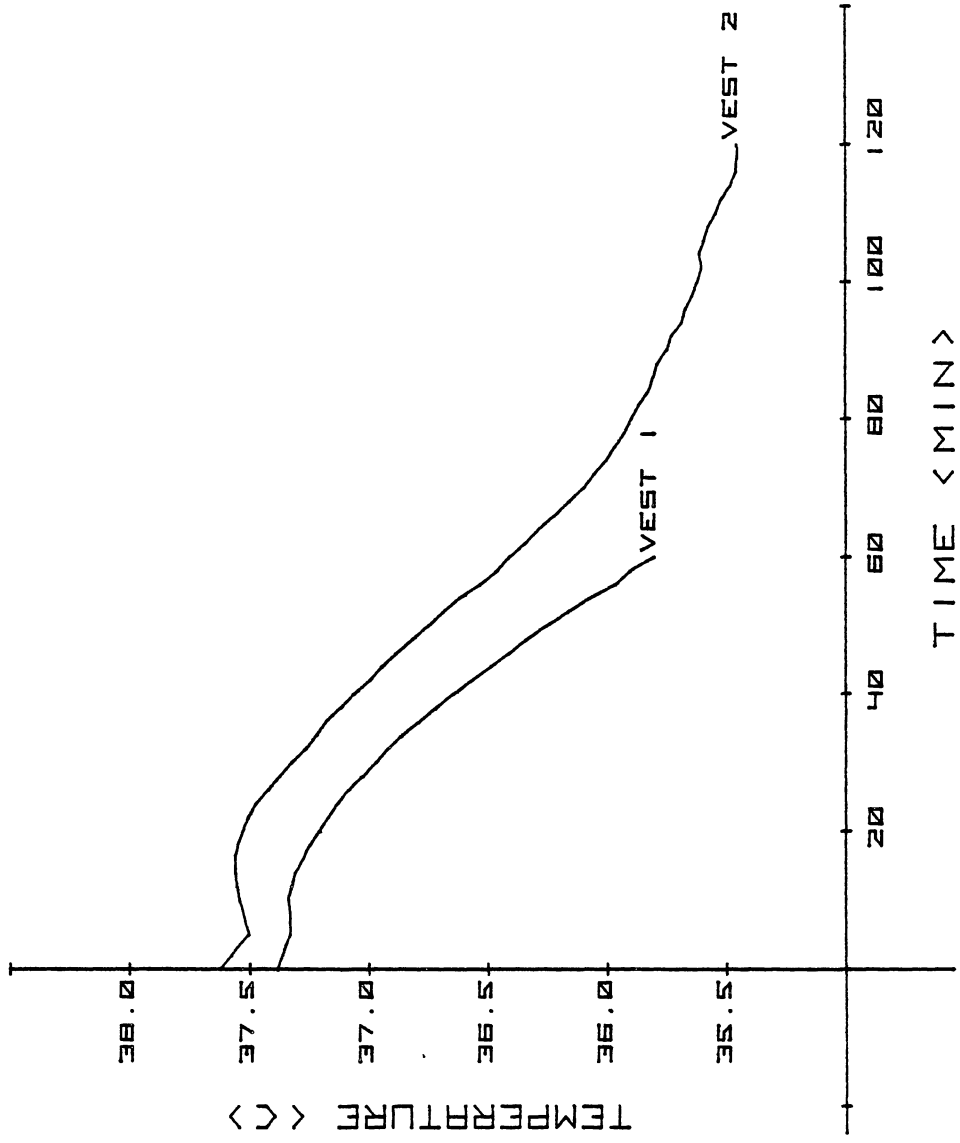


Figure 27. Rectal Temperature VS. Time During Immersion for Subject MJ

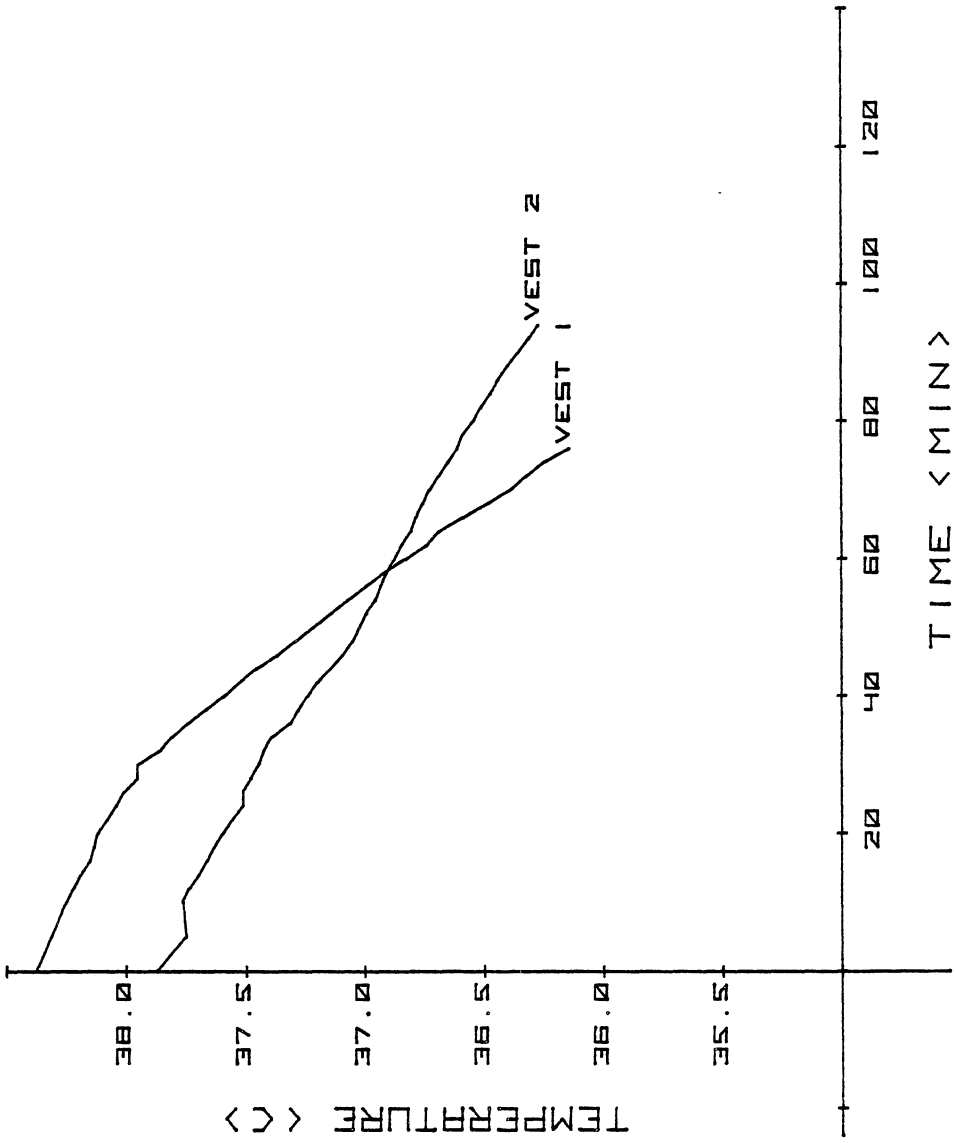


Figure 28. Rectal Temperature VS. Time During Immersion for Subject AR

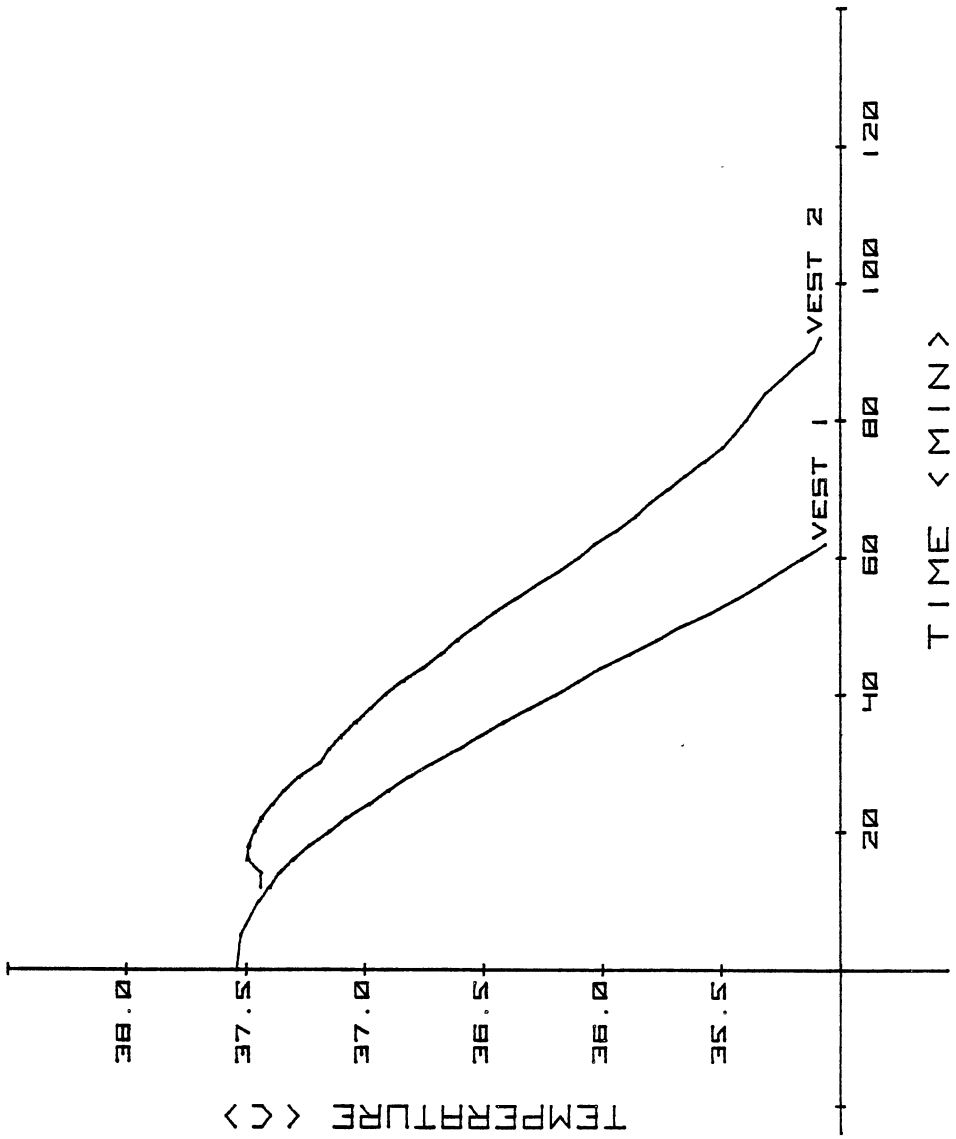


Figure 29. Rectal Temperature VS. Time During Immersion for Subject KT

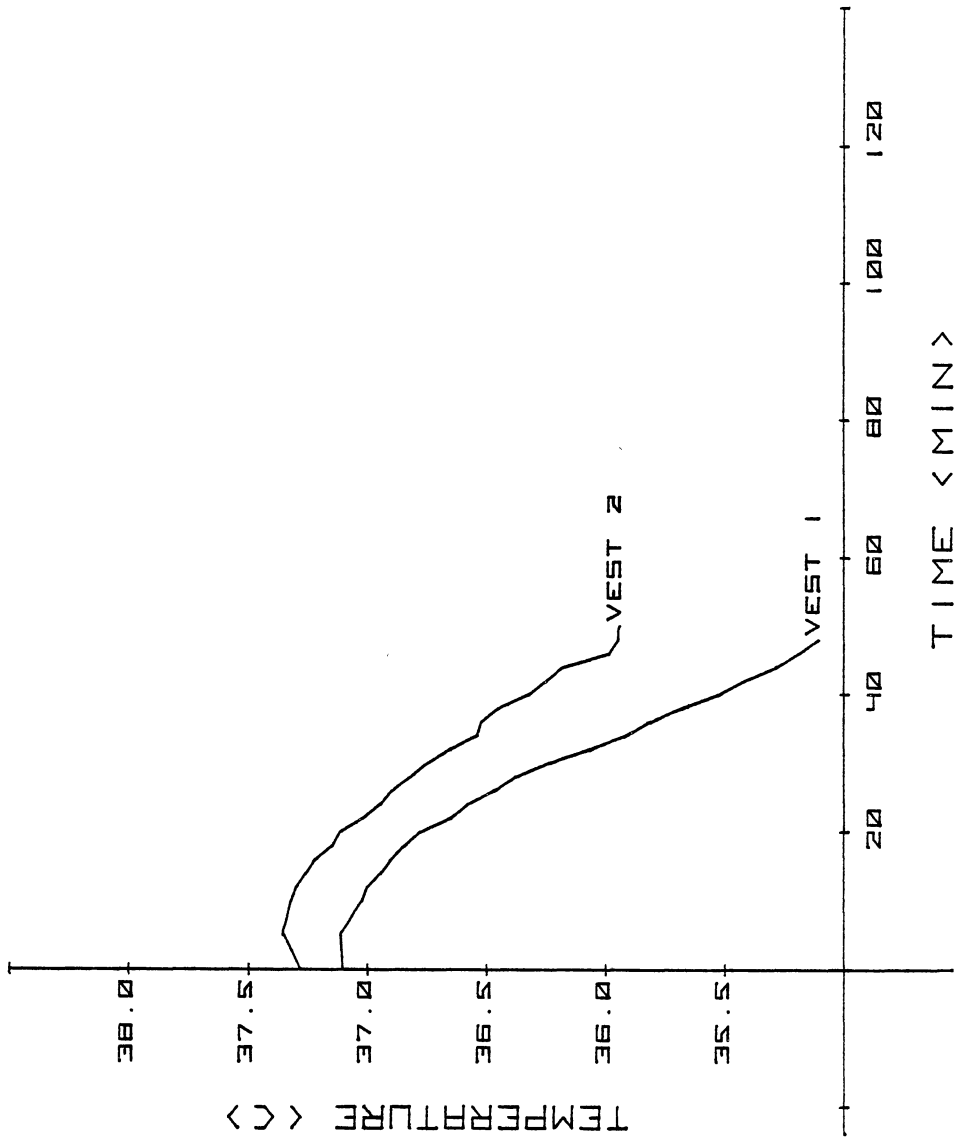


Figure 30. Rectal Temperature VS. Time During Immersion for Subject GR

VITA 2

Bernard J. Rueschhoff Jr.

Candidate for the Degree of

Master of Science

Thesis: DEVELOPMENT AND EVALUATION OF A THERMAL PROTECTIVE LIFE PRESERVER FOR COLD WATER IMMERSION

Major Field: Clothing, Textiles and Merchandising

Biographical:

Personal Data: Born in Hoxie, Kansas, March 4, 1955, the son of Leona Rueschhoff and Bernard J. Rueschhoff Sr.; married to Patricia Meier in 1980.

Education: Graduated form Salina South High School, Salina, Kansas, in May 1973; received the Associate of Science degree in Apparel Design in 1979; received the Bachelor of Science degree in Home Economics in 1982; completed the requirements for the Master of Science degree at Oklahoma State University in July, 1985.

Professional Experience: Assistant Designer (part-time), Green Brook Corporation, Miami, Florida, 1978; Custom Tailor, Verl Custom Tailor, Kansas City, Missouri, 1982; Head Tailor, Polo/Ralph Lauren, Kansas City, Missouri, 1983; Graduate Teaching Assistant, Clothing, Textiles and Merchandising Department, Oklahoma State University, 1984; Human Factors Specialist, Federal Aviation Administration, Oklahoma City, Oklahoma, 1984 to present.

Professional Organizations: American Home Economics Association, Oklahoma Home Economics Association, Association of College Professors of Textiles and Clothing.